Peak Load Forecast for Saudi Arabia Electric Power Generation, 1978 – 2000

by

Anwar Saeed Abdullah

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

ELECTRICAL ENGINEERING

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Abdullah, Anwar Saeed, M.S.

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This thesis, written by

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بسم الله الرحمن الرحيم

This thesis is dedicated to my parents.

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ABSTRACT

This is a long term peak load forecast of peak electrical demand for the entire Kingdom. This forecast discusses the availability of primary energy, development of a long range forecast of peak electrical demand, study and suggestions of the types of generation including nuclear and solar systems and finally recommends a procedure for a load forecasting methodology for the Kingdom of Saudi Arabia.

I. INTRODUCTION

Load forecasting has always been an integral part of power system planning and operation. However, it did not receive as much attention in the past as it deserves because the fuel supplies, especially hydrocarbons, were cheap and abundant, and utilities could find funds for erecting enough gas/oil generating plants at relatively short lead times. In the last few years, the conditions have considerably changed and the past practices will have to be suitably modified. Load forecasting will assume greater importance and therefore, it will receive more attention.

The basic potentialities for the economical development in any society are:

(1) Manpower.

(2) Material.

(3) Energy.

(4) Equipment.

Electrical Energy is considered the back-bone for the construction of the economical and social structures in the Kingdom of Saudi Arabia.

Correct planning of electrical power schemes has to satisfy two main requirements:

(1) Reliable availability of Electrical Energy.

(2) Its delivery at the sites of the load demands at the optimum lowest cost per unit energy.

Normally, electrical power schemes need a comparatively long lead-years for studies, contracting, and construction before being connected on-line.

Therefore, it is essential for a country to have an electrification plan for the coming years ahead, in order to secure proper scheduling and correct timing for the operating of new electrical power projects. The electrification plan should take into account the World Energy Strategy. It also has to take full account of the future developments in Energy Systems.

This work is an M.S. Thesis study of the models of Economics of generation in the Electrification Plan for Saudi Arabia. Since 1966, dual purpose power and water generating plants have been established as the most economical for the present and future utilization in the national grid power systems.

However, comprehensive studies of the availability of energy sources and the economics of power generation are needed even when conventional fuels, such as national oil resources, are used. Local regional conditions, especially sites where the major

Electrical and Water demands exist, prospective regional economic and social development, and the regional availability of water supplies, are factors which have a very significant influence upon the modes and economics of the regional and national generation and supply of electrical energy.

Thus we have to deal with the following items:

1. Availability and economics of primary energy.

2. Development of a long range forecast of peak electrical demand in Saudi Arabia.

3. Studies of the various feasible modes of conventional electric generation and recent developments, and also the technical feasibility for regional generation.

4. Use of other sources of energy for electric generation, such as nuclear and solar energy.

5. Presentation of a study of dual purpose power and water generation in Saudi Arabia.

6. Recommend procedures for a Load Forecasting Methodology for the Kingdom of Saudi Arabia.

II. PRIMARY ENERGY AND ECONOMICS IN SAUDI ARABIA

2.1. INTRODUCTION

Energy is a fundamental concept involving the capacity of doing work. The sources of energy can be divided into two categories: energy capital and energy income.

Energy capital is due to the storage of solar energy in chemical form by the action of living organisms millions of years ago. Energy income is replenished, either instantaneously by the direct use of solar energy, or after a short period of storage in the form of winds, rivers, waves, etc.

Among energy sources are:

(1) Oil.

(2) Natural gas.

(3) Nuclear energy.

(4) Hydraulic energy.

(5) Solar energy.

(6) Coal.

(7) Geothermal energy.

(8) Wind energy.

Figure 2.1 classifies these sources of energy with respect to the two mentioned categories |23|. Fossil fuels are indeed the most used primary sources of energy today and supply about 85% of the world's present need. The "Energy Administration For Research And Development" reports that in the year 2020, World energy will be supplied by oil, coal, nuclear and solar energy with 20% for each, while the remaining 20% will be supplied by natural gas and geothermal energy.

2.2. OIL RESERVES AND PRODUCTION IN SAUDI ARABIA

2.2.1 Oil Reserves:

At the end of 1978, Aramco's estimated that probable crude oil reserves amounted to 177.8 billion barrels (1.03066Q) of which 113.3 billion barrels (0.65714Q) were proved reserves. Table 2.1 shows the oil reserves since 1973 |2|.

Figure 2.2 shows the statistical summary of estimated petroleum reserves in Aramco concession |2|. A map scaled to show comparative oil reserves in the world in 1978, is shown in Fig. 2.3 |3|. The top country in the proved oil reserves is Saudi Arabia |3|. Table 2.2 shows the top ten countries in proved oil reserves |3|.

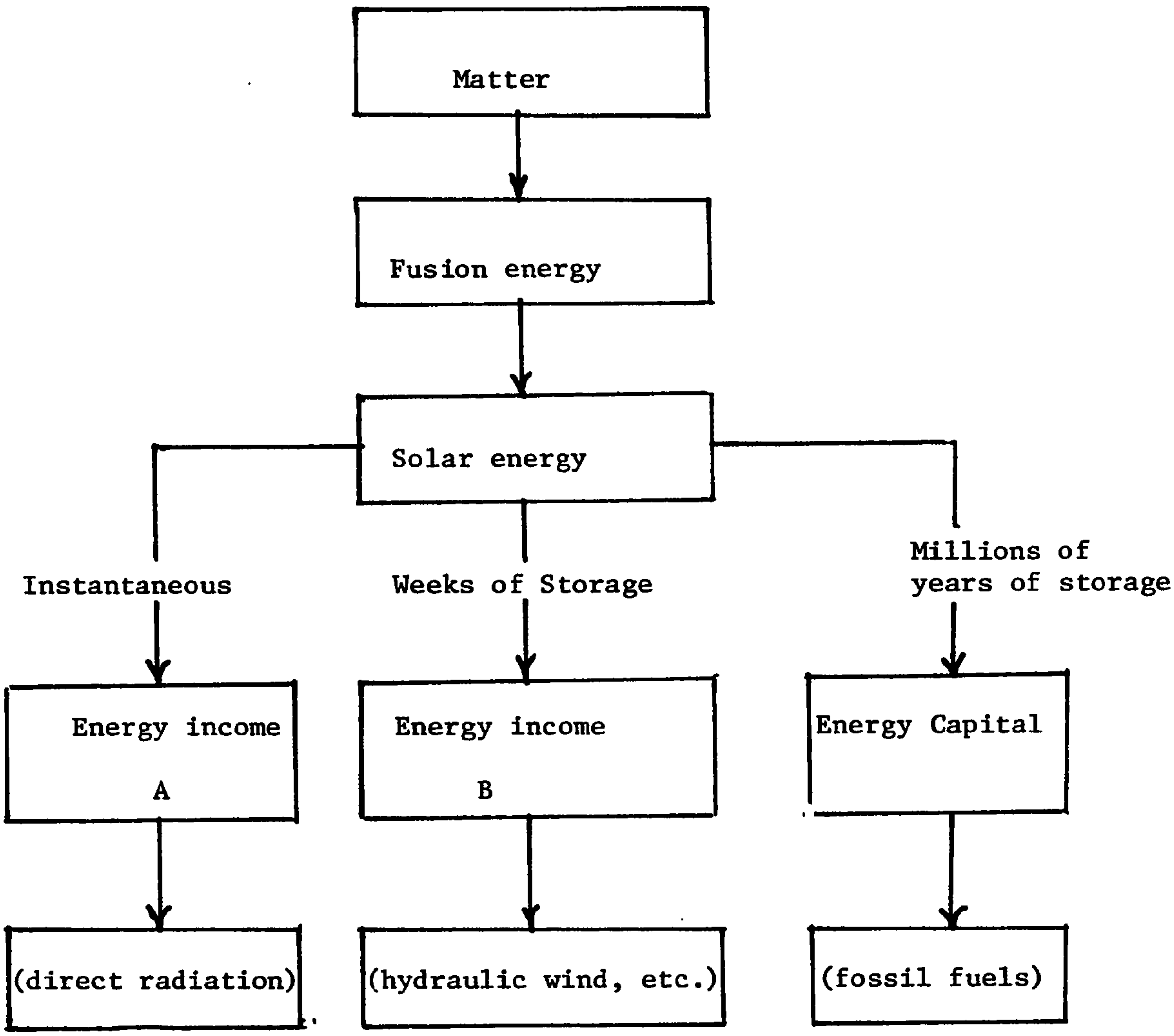


Figure 2.1. Energy income and energy capital, all originating from the sun and from matter. The difference is in the duration of the storage period.

TABLE 2.1. Estimated Aramco Petroleum Reserves.

	Proved Reserves		Probable Reserves*	
Year End	Million of barrels	10^{18} Btu=Q unit	Million of barrels	Q unit
1973	96,922	0.5621	164,520	0.9542
1974	103,480	0.6002	172,529	1.0006
1975	107,857	0.62557	175,759	1.019402
1976	110,187	0.63908	177,532	1.02969
1977	110,443	0.64057	177,642	1.03032
1978	113,284	0.65714	177,758	1.03100

* Probable reserves include proved reserves

1 Barrel of crude oil = 5,800,000 Btu.

Q unit = 10^{18} Btu.

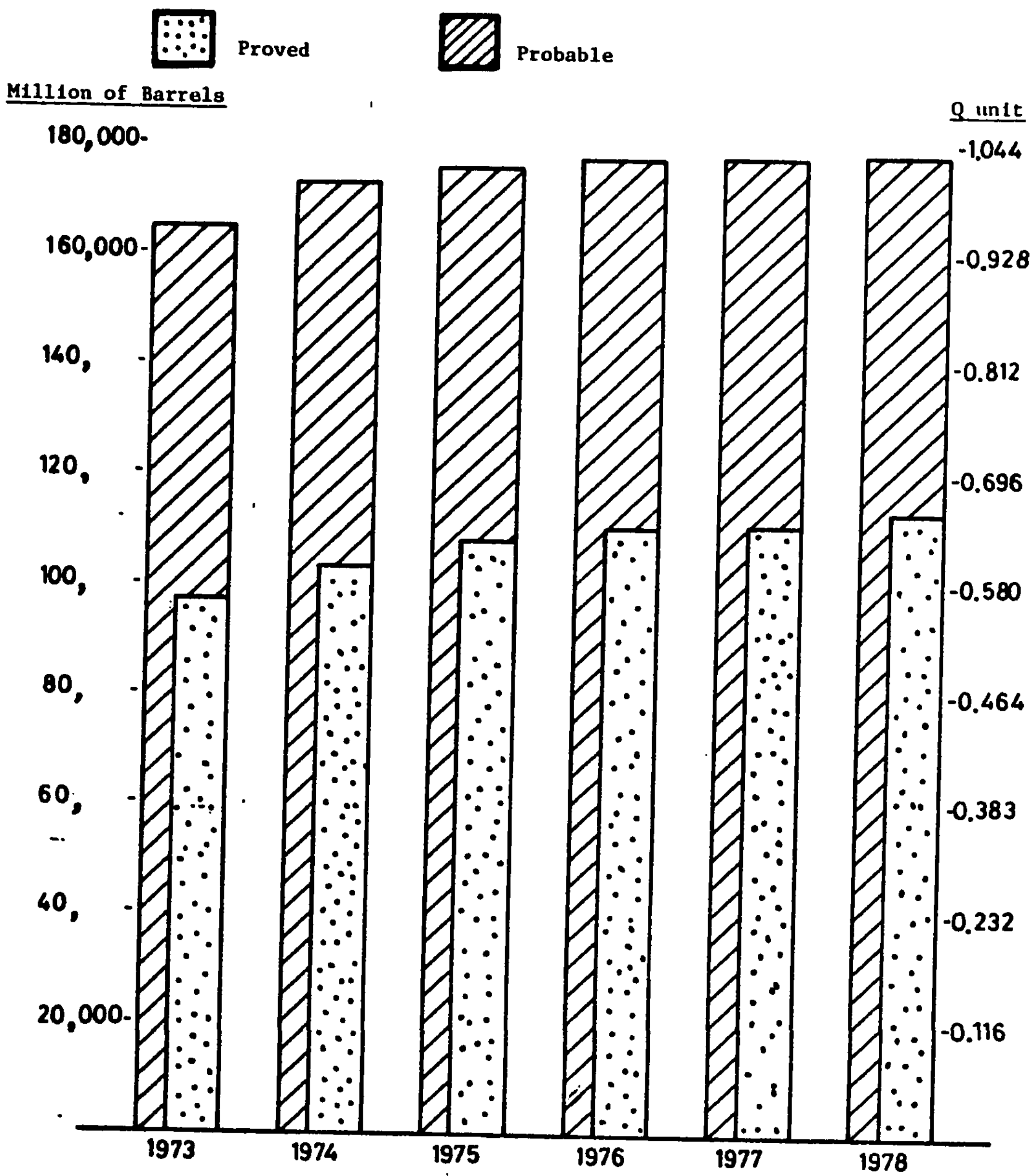


Figure 2.2. Estimated Petroleum Reserves in Saudi Arabia.

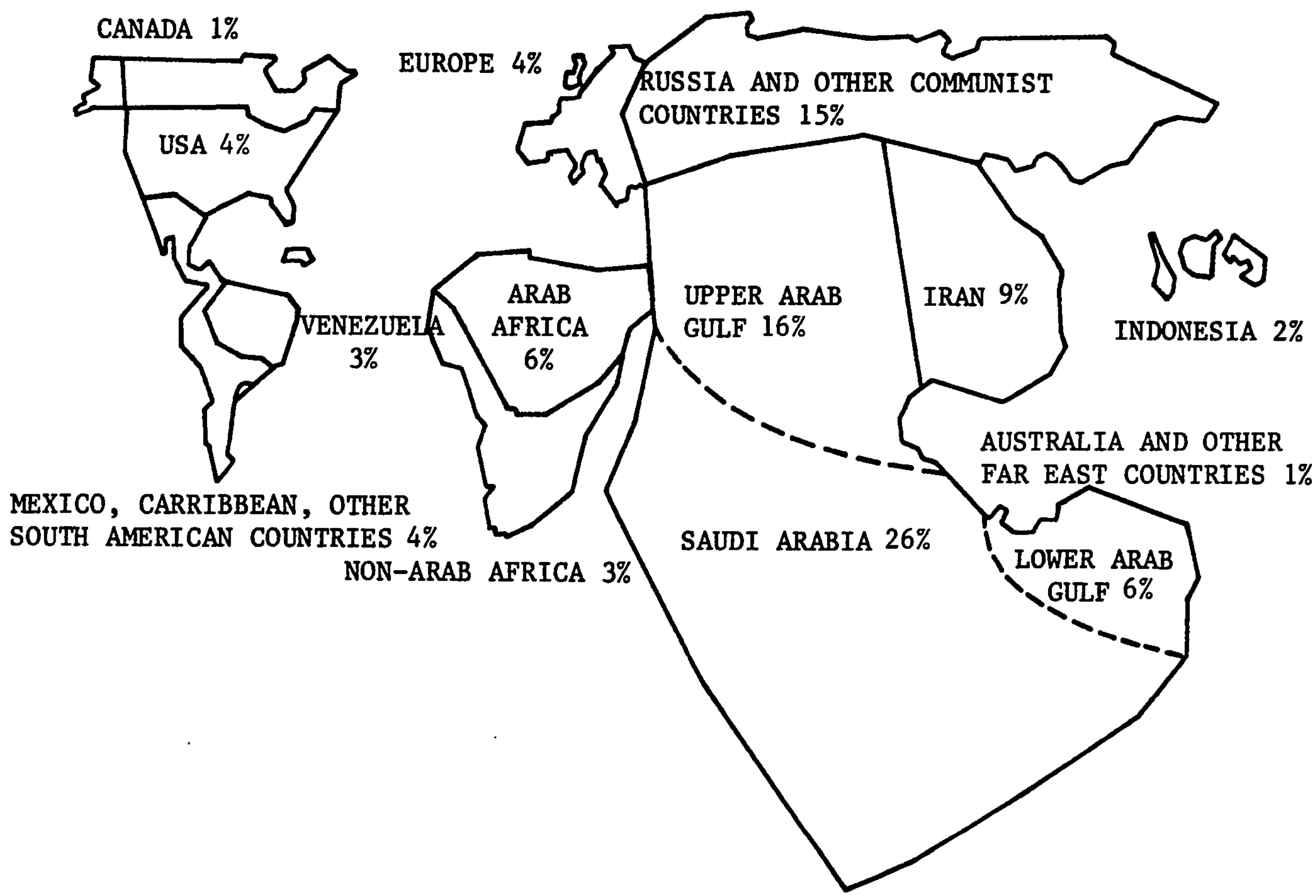


Figure 2.3. Map Scaled to show comparative oil Reserves in the world (1978).

TABLE 2.2. Top Ten Countries in Proved Oil Reserves End 1978.

		In million of barrels	In Q unit
1.	Saudi Arabia**	168,940	0.9798
2.	U.S.S.R.	71,000	0.4118
3.	Kuwait**	69,440	0.4028
4.	Iran	59,000	0.3422
5.	Iraq	32,100	0.1862
6.	Abu Dhabi	30,000	0.1740
7.	U.S.A.	28,500	0.1653
8.	Libya	24,300	0.1409
9.	China	20,000	0.1160
10.	United Kingdom	18,200	0.1056
	Top Ten Countries Total:	521,480	3.0246

** Includes one half of the Partitioned Neutral Zone reserves. Total estimated proved oil reserves end 1978 approximately 2.4Q in the Middle East and North Africa.

2.2.2 Oil Production:

In 1978, Saudi Arabian crude oil production represented 14% of the World output (Fig. 2.4), |3| 30% of OPEC-MEMBER production and 45% of the Arab Nation output. Before 1944 Saudi Arabia produced less than 20,000 barrels a day (0.116×10^{-6}Q), its production rose up to 500,000 barrels/day (2.9×10^{-6}Q) by the end of 1949. From 1950 through 1969, the amount of crude oil produced by Saudi Arabia increased by an average annual rate of about 9%.

By 1970, daily average production had reached 3,548,865 barrels (20.58×10^{-6}Q), a rate that almost tripled over the next few years, reaching 9,016,952 barrels (52.3×10^{-6}Q) in 1977.

Aramco is the largest crude oil and natural gas liquids (NGL) producing company in the World. Its crude oil production of 2.944 billion barrels (0.017Q) in 1978 amounted to about 98 percent of Saudi Arabia's total production. Cumulative crude oil production from 1938 through the end of 1978 totaled 33.7 billion barrels (0.195Q). Fig. 2.5 shows the statistical summary of oil production since 1938. |2|

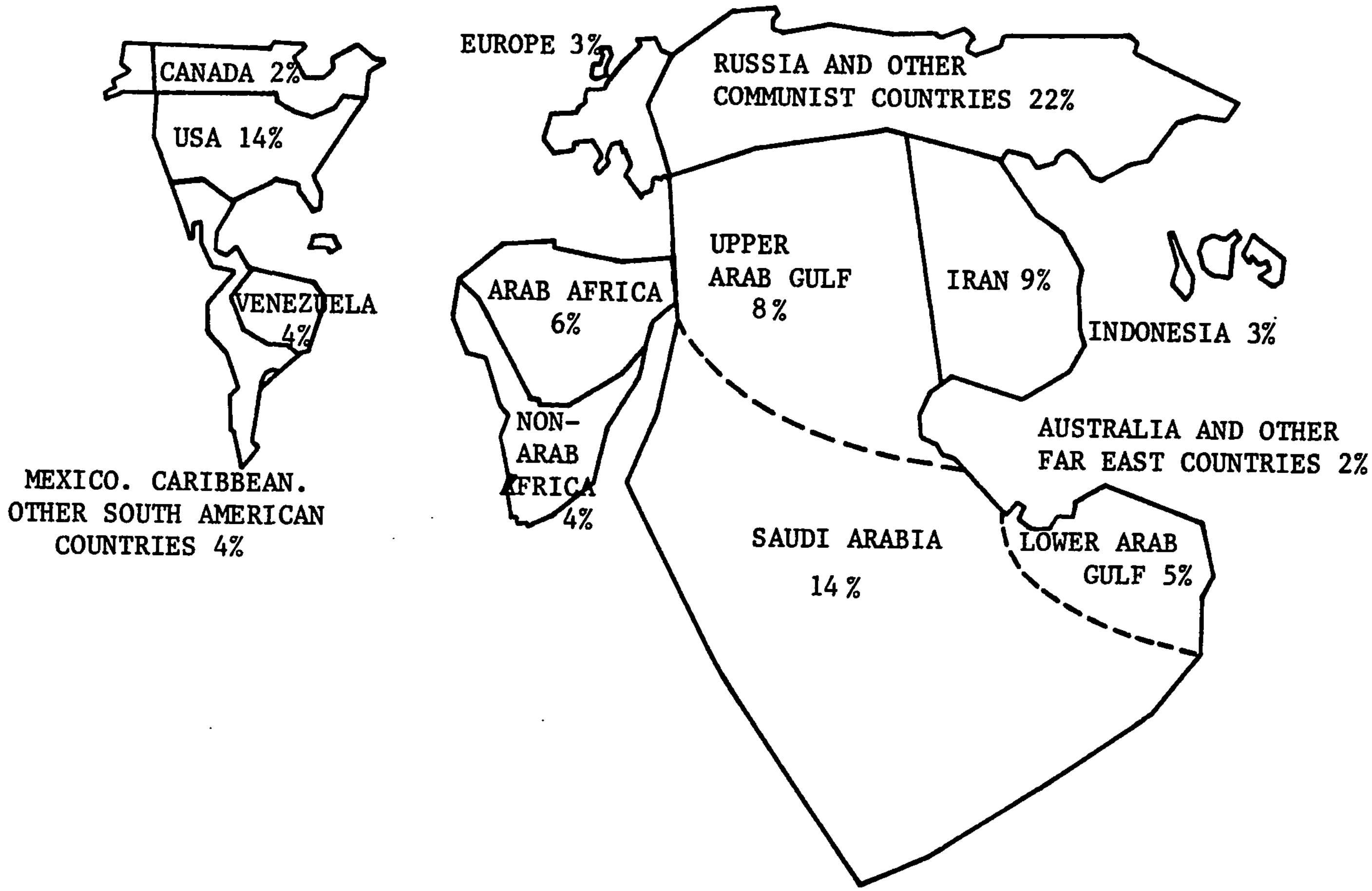


Figure 2.4. Map Scaled to show Comparative Oil production in the world (1978).

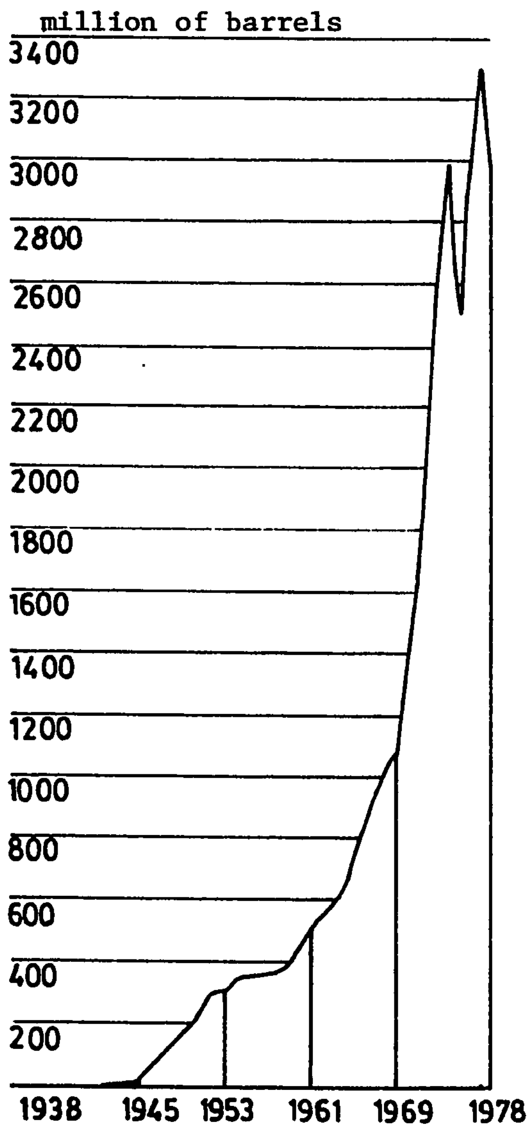


Figure 2.5. Crude Oil Production in Saudi Arabia.

The present intention is to increase the output to 12 million barrels daily (69.6 x 10^{12} Btu daily) (i.e. 4.38 billion barrels per annum which equal 0.0254 Q/year). However, the policy of crude oil production has to be revised and synchronized between the rate of production and the actual needs for economical and social development.

At present 98% of the oil production is exported.

2.2.3 Present and Future Expansions in the Refinery Capacities:

The total refinery capacity in Saudi Arabia in 1978 was 518,000 barrels daily. There are three refineries in Saudi Arabia:- the largest one is in Ras Tanura with a capacity of 415,000 barrels daily, the second one is in Jeddah with a capacity of 85,000 barrels daily, and the third one is in Riyadh with total capacity of 18,000 barrels daily. The present and future expansions in the refinery capacities are shown in Table 2.3.

The total refinery capacity in 1988 is estimated to be 1,700,000 barrels per day (i.e. 0.62 billion barrels per annum).

TABLE 2.3. Present and Future Expansions in the Refinery Capacities.*

	Eastern	Central	Western	Total
Operating 1978	415,000	18,000	85,000	518,000
Planned 1988	620,000	132,000	490,000	1,242,000
Regional total	1,035,000	150,000	575,000	1,760,000

* Source: Petromin - Jeddah - Saudi Arabia, 1978.

2.2.4 Oil Prices:

The World market price for crude oil at RAS-TANURA has increased in seven years from \$ 1.8 per barrel in 1970 to \$ 12.09 in 1977, and to \$ 19.5 at the end of June, 1979. The organization of Petroleum Exporting Countries (OPEC) keeps close attention on the adjustment of the market price in accordance with varying international, political, economical and social circumstances. The monetary function of the U.S. dollar, and the continuing rises of import prices are matters of major concern to OPEC. The market price for crude oil \$ 19.5 per barrel in 1979 is equivalent to \$ 3.39 per 10^6 Btu based on HHV (Higher Heating Value).

The continuous rise in the price for crude oil is shown in Table 2.4.

2.2.5 Oil Consumption:

Saudi Arabia consumed in 1978 approximately 60,000,000 barrels which equals approximately 0.55% of the demand in the United States. Appendix A shows the consumption of oil since 1968 in Saudi Arabia. Figures 2.6 and 2.7 show the consumption of oil since 1968 in Saudi Arabia.

Saudi Arabia consumed 1.5% of its total production in 1978. This ratio was only 0.36% in 1973.

TABLE 2.4. Price for Crude Oil (1971-1979).

Date	Cost $/barrel
January 1971	1.8
July 1971	2.29
January 1972	2.479
June 1972	2.591
October 1973	5.119
January 1974	10.52
January 1975	11.651
January 1977	12.091
December 1978	14.00
End of June 1979	18.0 - 21.50

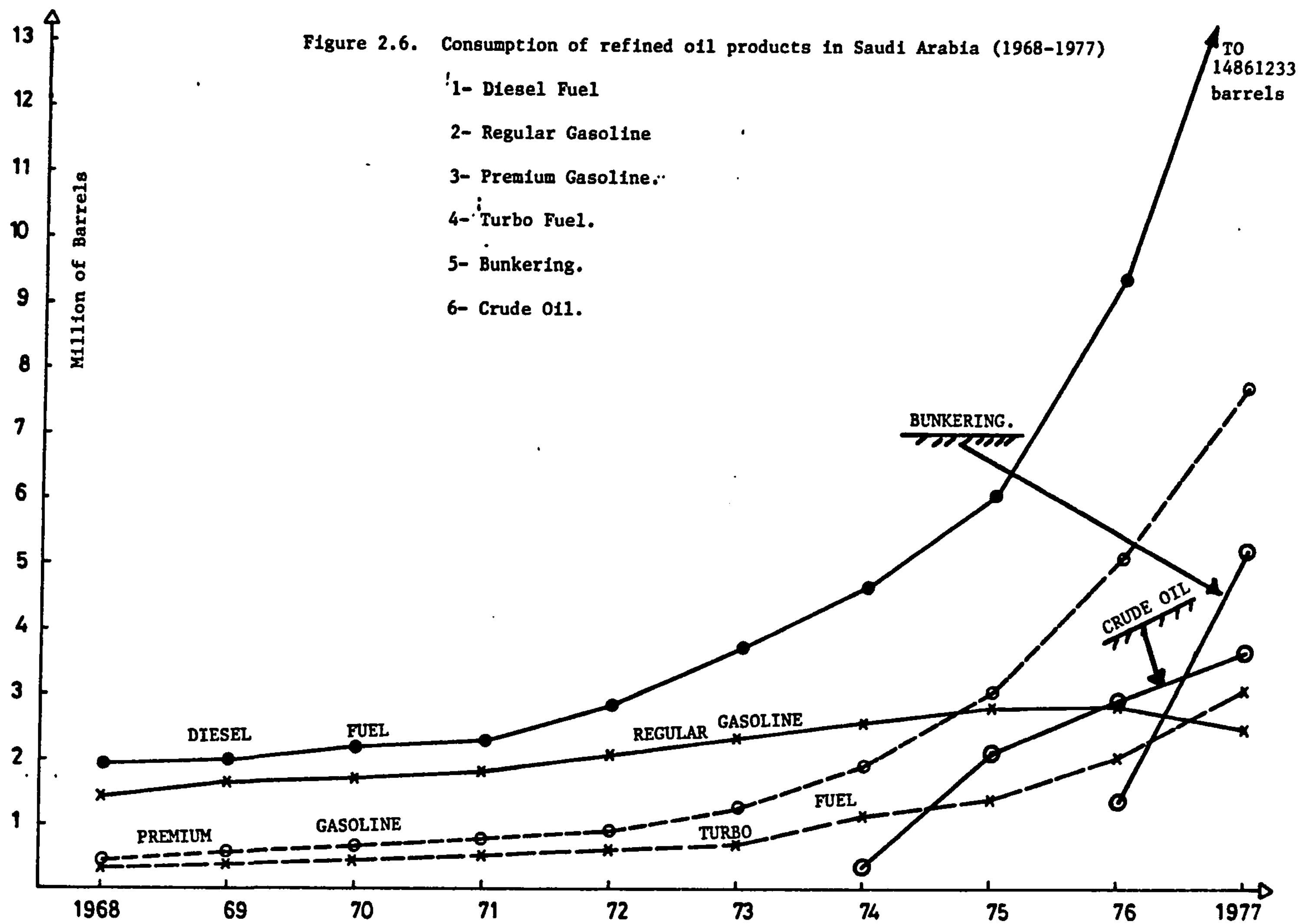


Figure 2.6. Consumption of refined oil products in Saudi Arabia (1968-1977)

1- Diesel Fuel

2- Regular Gasoline

3- Premium Gasoline.

4- Turbo Fuel.

5- Bunkering.

6- Crude Oil.

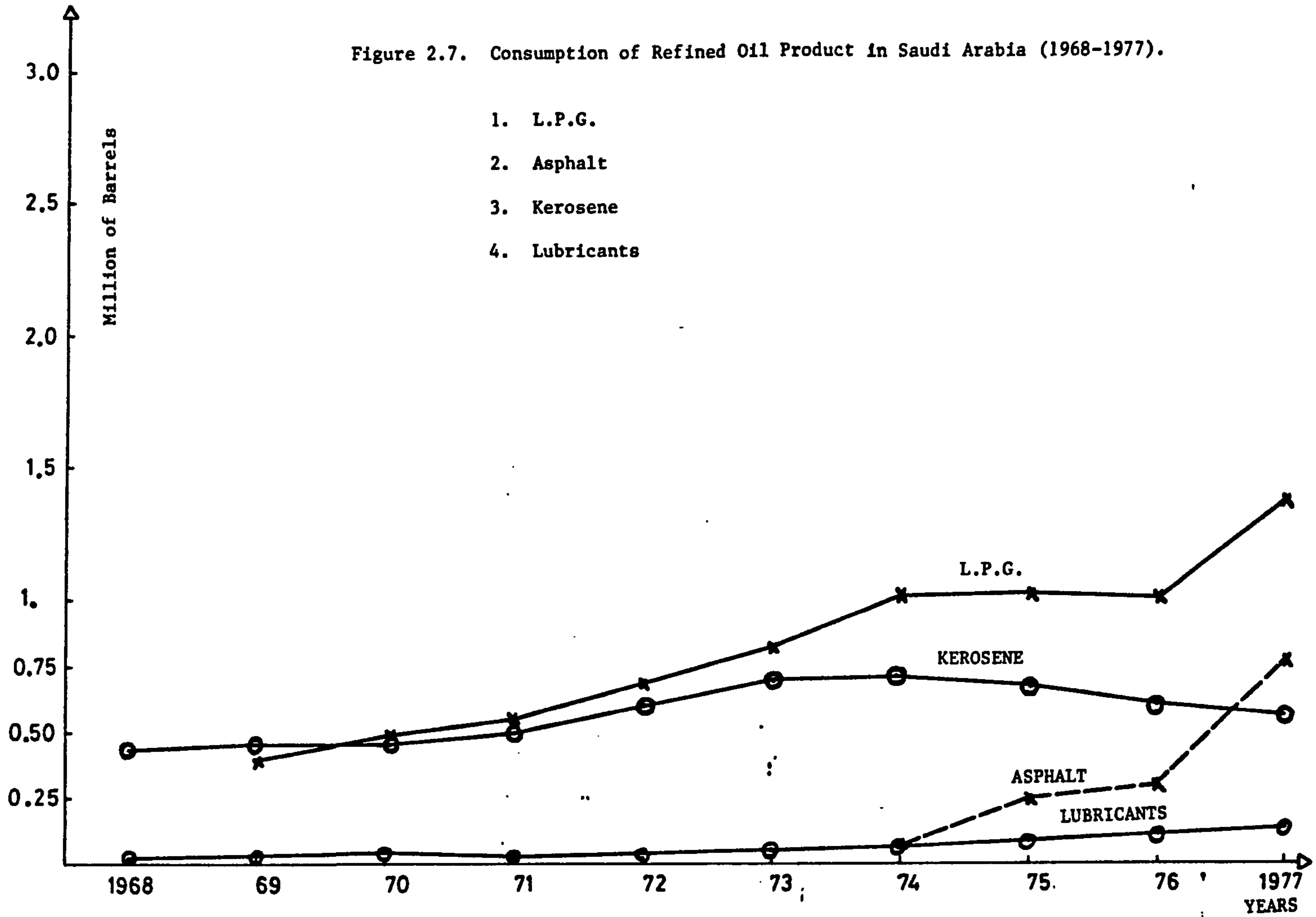


Figure 2.7. Consumption of Refined Oil Product in Saudi Arabia (1968-1977).

2.3. GAS RESERVES AND PRODUCTION

2.3.1 Gas Reserves:

At the end of 1978, Aramco's estimated probable gas reserves amounted to 112,912 billions of cubic feet (0.10915Q) of which 66,715 billions of cubic feet (0.064491Q) were proved reserves (Table 2.5). |3|

2.3.2 Gas Production:

Gas production is associated with oil production, and 17.8% of it was consumed in gas-injection, power generation, and industrial uses, the excess gas was burn-up in 1978.

Saudi Arabia plans to collect gas at the rate of 1.6 billion cubic feet per day (1.55×10^{12} Btu/day) by 1985 and plans full recovery. In the future, gas collection will rise upto 3.6 billion cubic feet per day (3.48×10^{12} Btu/day) of natural gas and natural gas liquid.

Gas development in Saudi Arabia has just begun and fractionation facilities are just completed in JU'AYMAH (Eastern Region) and similar facilities are planned in YANBU' (Western Region). Several major projects are planned for utilizing this gas reserve in new industries such as petrochemical industries, steel production in addition to power and desalination plants such as AL-JUBAIL project.

TABLE 2.5. Estimated Aramco Gas Reserves.

YEAR END	PROVED RESERVES			PROBABLE RESERVES		
	Billion of ft^3	Billion Barrels	10^{12} Btu	Billion of ft^3	Billion Barrels	10^{12} Btu
1978	66,715	11.12	64,491	112,912	18.82	109,148
1977	62,406	10.4	60,320	111,406	18.57	107,706
1976	63,759	10.63	61,654	113,646	18.94	109,852
1975	62,290	10.38	60,204	109,514	18.25	105,850
1974	60,963	10.16	58,928	105,481	17.58	101,964
1973	56,126	9.35	54,230	107,378	17.9	103,820

* 6000 ft^3 of natural gas is equivalent to 1 barrel of oil

* 1 barrel of oil = 5.8×10^6 Btu

* $Q = 10^{18}$ Btu

2.3.3 Gas Consumption:

Aramco used most of the gas consumed in Saudi Arabia, mostly in power generation. In Saudi Arabia, natural gas is produced with crude oil.

Table 2.6 shows the consumption of natural gas in Saudi Arabia excluding Aramco. This consumption record since 1973 is for

1) DEPCO (DHAHRAN ELECTRIC POWER COMPANY).
2) SAFCO (SAUDI FERTILIZER COMPANY).
3) FAISEL PROJECT IN HARADH.
4) AZIZIA DESALINATION PLANT IN KHOBAR.
5) SAUDI CEMENT.
6) AL-TURKI PLANT.
7) AL-DOSSARY PLANT.
8) AL-DURBAS PLANT.
9) N. GLASS FACTORY.
10) UNIVERSITY OF PETROLEUM & MINERALS.

DEPCO, SAFCO, FAISEL PROJECT and AZIZIA DESALINATION PLANT obtain their gas free. The others are charged small rate. In 1977 more than 40% of natural gas consumption in Saudi Arabia was consumed by power generators excluding Aramco.

TABLE 2.6. The Consumption of Natural Gas in Saudi Arabia (Non Aramco's).

	1973		1974		1975		1976		1977	
	MSCF	BARRELS	MSCF	BARRELS	MSCF	BARRELS	MSCF	BARRELS	MSCF	BARRELS
DEPCO	4521867		4600364		5364429		9705472		16220134	
SAFCO	14168264		10489346		11169056		12436875		14305043	
K. FAISEL PROJECT	-		966692		1326576		963096		1213842	
AZIZIA DISILINATION	1139663		1238310		1312219		1721064		1915281	
SAUDI CEMENT	2715716		2907958		3767981		3200749		3370114	
AL-TURKI PLANT	27143		28829		26933		20759		286	
AL DOSSARY PLANT	22749		35899		36179		35904		35881	
AL DURBAS PLANT	27253		33417		19700		22654		969	
N. GLASS FACTORY	178864		137770		86198		98113		123001	
UNIV. OF PET. & MINERALS	28119		25977		21830		7091		8435	
TOTAL FREE	19829794		17294712		19172280		24826507		33654300	
TOTAL SALES	2999846		3169940		3958821		3385259		3538686	
G. TOTAL	22829640	4794224	20464652	4297577	23131101	4857531	28211766	5924471	37192986	7810524
		27.8×10^{12} Btu		24.9×10^{12} Btu		28.2×10^{12} Btu		34.4×10^{12} Btu		45.3010 Btu

IMSCF = Millions Cubic Feet

1 Barrel = 0.21 x MSCF 1 Barrel = 5.8×10^{6} Btu

2.4. NUCLEAR ENERGY

There is no discoveries of uranium but there are plans for the exploration of uranium prospects. |30|

2.5. HYDRAULIC ENERGY

Natural and main mode water falls (e.g. dams and barrages with heads and reliable water discharges adequate for hydro-electric generation) are not available in the Kingdom of Saudi Arabia.

2.6. SOLAR ENERGY

It is available in a huge quantity (Saudi Arabia receives approximately 105 x 10^{12} KWh of solar energy daily - thermally equivalent to 10 billion barrels of oil). |25| But there is no economical uses of this energy in Saudi Arabia at present. A common project of research is underway between Saudi Arabia and the U.S. amounting to a total of $ 100,000,000 in 5 years.

2.7. COAL

There are no known reserves of coal in Saudi Arabia at present.

2.8. GEOTHERMAL ENERGY

Minimum data about the geothermal potential in Saudi Arabia is available. The use of geothermal energy for power generation in Saudi Arabia might be practical, but considerable research and field investigation must be undertaken first. |40|

2.9. WIND ENERGY

The generation of electricity by wind is not dependent on new technology. However, because of its varying nature, wind energy requires a supplemental source of power as backup. The wind generator can serve conventional fuels, but can not displace conventional onces. In addition, wind generators have a low capacity factor. As such, wind driven power plants would require an energy storage system if they were to supply reliable power. Practical storage systems which could be conveniently applied to a large station are not currently available.

Wind Energy may find application in some remote areas, but should not be expected to supply much energy in the next 20 years.

2.10. CONCLUSION

The worldwide demand for petroleum products when combined with availability and refinery capacity in Saudi Arabia, indicates that any long-range generation plan should provide generating units capable of burning a variety of fuels. This situation is occasioned by the fact that at the present time, and well into the future, planned electric production fuel requirements exceed projected refinery capacity. Thus, electric generation in the Eastern Region during the coming years would use crude oil and natural gas. By 1988, it is probable that usage would shift to fuel oil and natural gas, provided that refinery capacity is expanded to meet the demand.

Also, the preferred fuels for peak load generators such as combustion generators and diesel-electric generators are diesel oil and, where and when available, natural gas.

III. DEVELOPMENT OF A LONG RANGE FORECAST OF PEAK ELECTRICAL DEMAND IN SAUDI ARABIA

3.1. INTRODUCTION

A long range plan for a power system is essentially a picture of how the system should grow from now to the year 2000, given certain assumptions and judgements about future loads, fuel sources and costs, etc.

Any plan, however, can become absolete in due time. New inventions in electrical utilization equipment or unforeseen industrial, commercial, or residential projects can change load forecasts. Breakthroughs in new generation and transmission technology, unexpected inflation in equipment or labour costs, or changes in primary fuel availability or cost can all mean that system plans should take a new direction. Finally, improvements in planning methodologies are regularly being made. For these and a variety of other reasons peak load forecast plans must be re-evaluated regularly.

3.2. ELECTRICAL LOAD REGIONS

In order to develop the electric load forecast for Saudi Arabia, the projected loads can be grouped into three reasonably well defined regions, namely, East, Center and West.

These regions, shown in Fig. 3.1 are characterized by specific population densities and industrial concentrations and thus prospective electric load densities. Their choice is influenced by geographical factors. The three regions are separated by distances of roughly 300 km and 800 km respectively, with only scattered loads in between.

The Eastern Region (Fig. 3.2) consists primarily of loads in the vicinity of Dammam, Khobar, Ras Tanura, Jubail, Abqaiq, Al-Hasa. Most of the load in this region is presently associated with oil production. The Saudi Consolidated Electric Company (SCECO) is responsible for the electric systems in the Eastern Province.

The Central Region (Fig. 3.3) includes the provinces of Riyadh, Qasim, and Hail, encompassing the cities of Riyadh, Al-Kharj, Zilfi, Buraydah, Unayzah, Hail, and Ar-Rass. Different companies such as Riyadh Electric Company, etc. are responsible for the electric system in the Central Region.

The Western Region (Fig. 3.4) is comprised of the provinces of Asir, Al-Bahah, Jizan, Mecca, Medina, Tabuk, and Najran, with the major electrical load concentrated in the cities of Jeddah, Mecca, Taif, Medina, Jizan, Abha, Khamis Mushait, Tabuk, and the proposed Yanbu' industrial complex. Different companies such as Jeddah Electric Company, etc. are responsible for the electric systems in the Western Region.

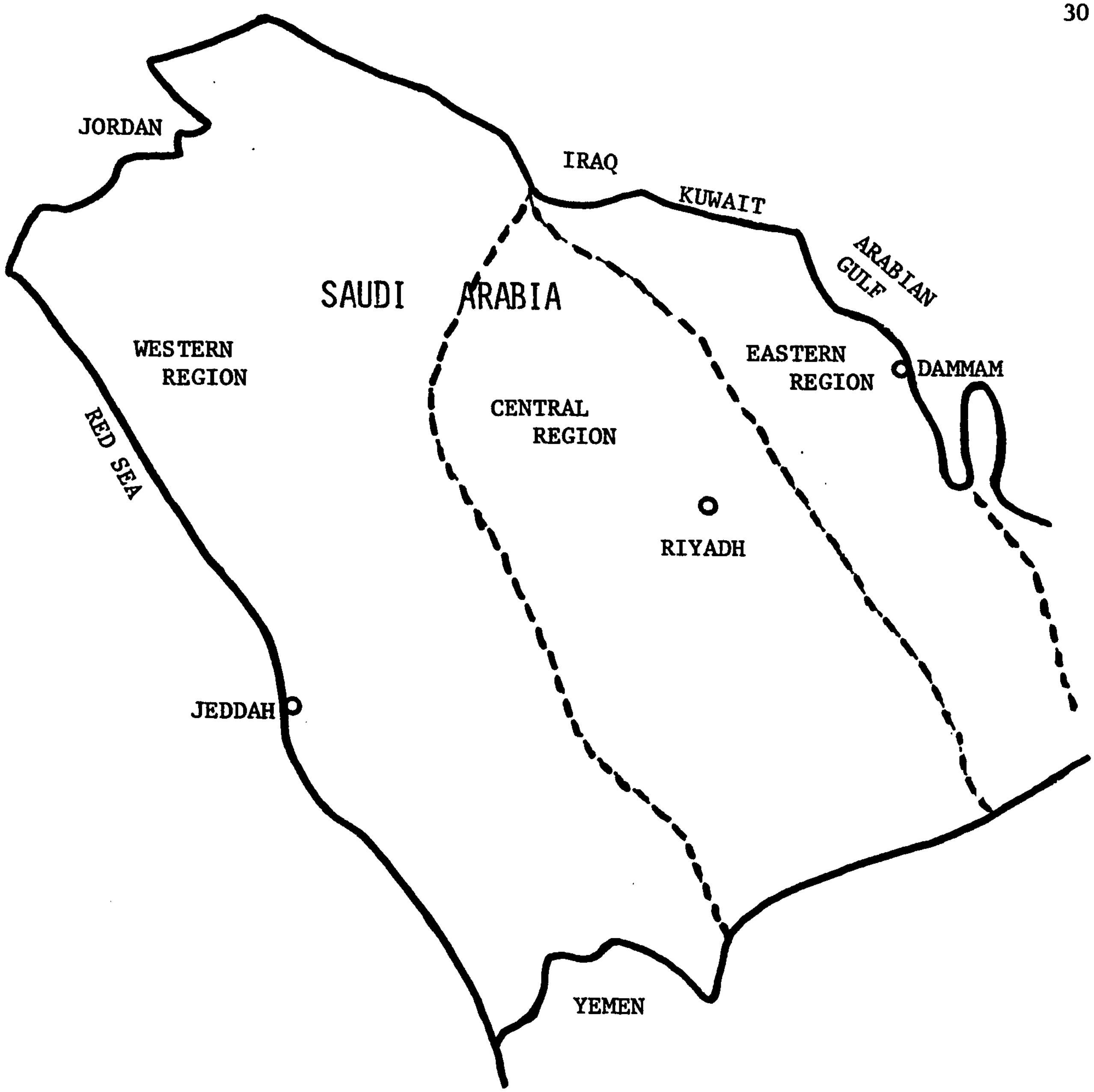


Figure 3.1. The Electrical Load Regions of Saudi Arabia.

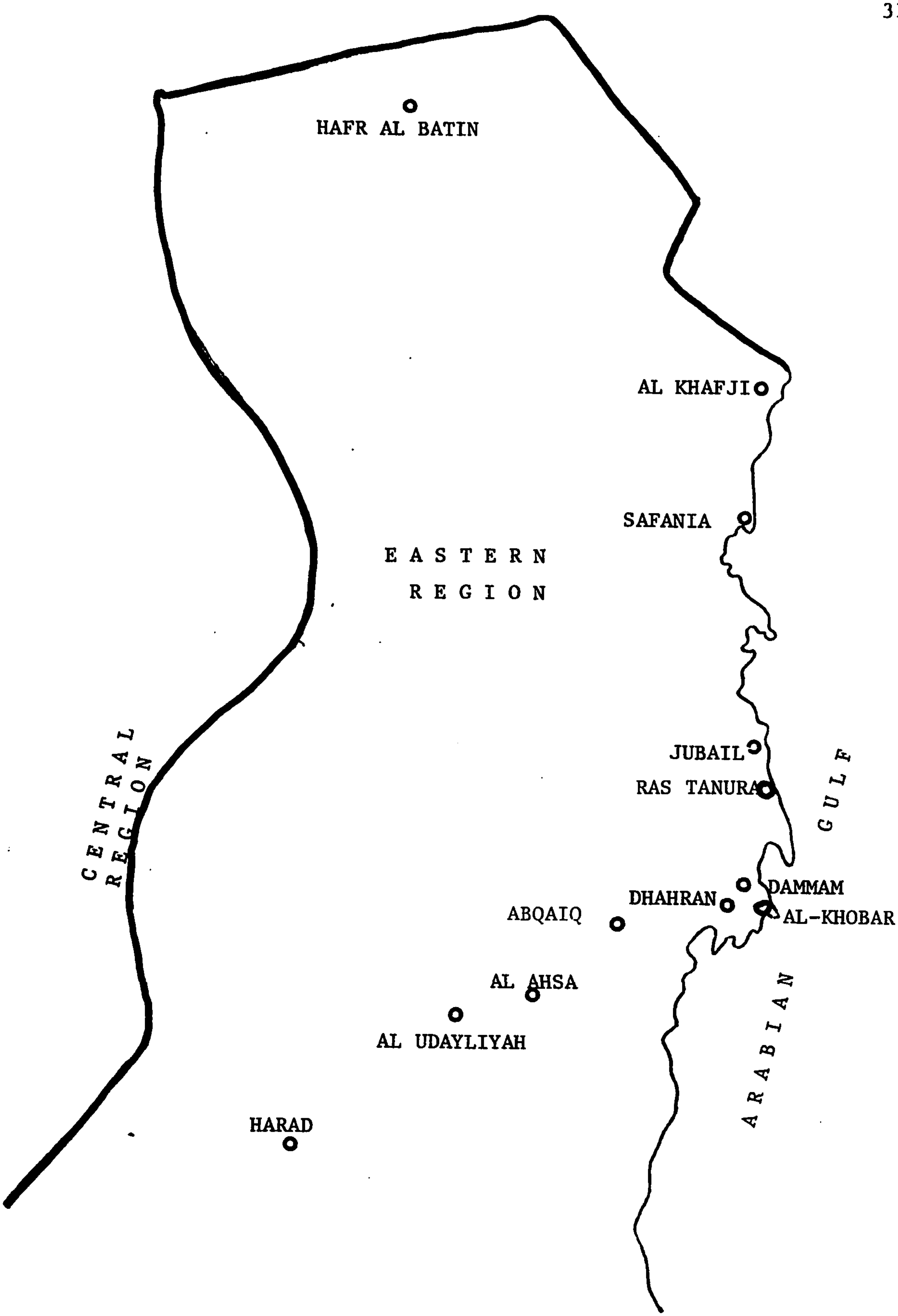


Figure 3.2. Major Electric Peak Load Location in the Eastern Region.

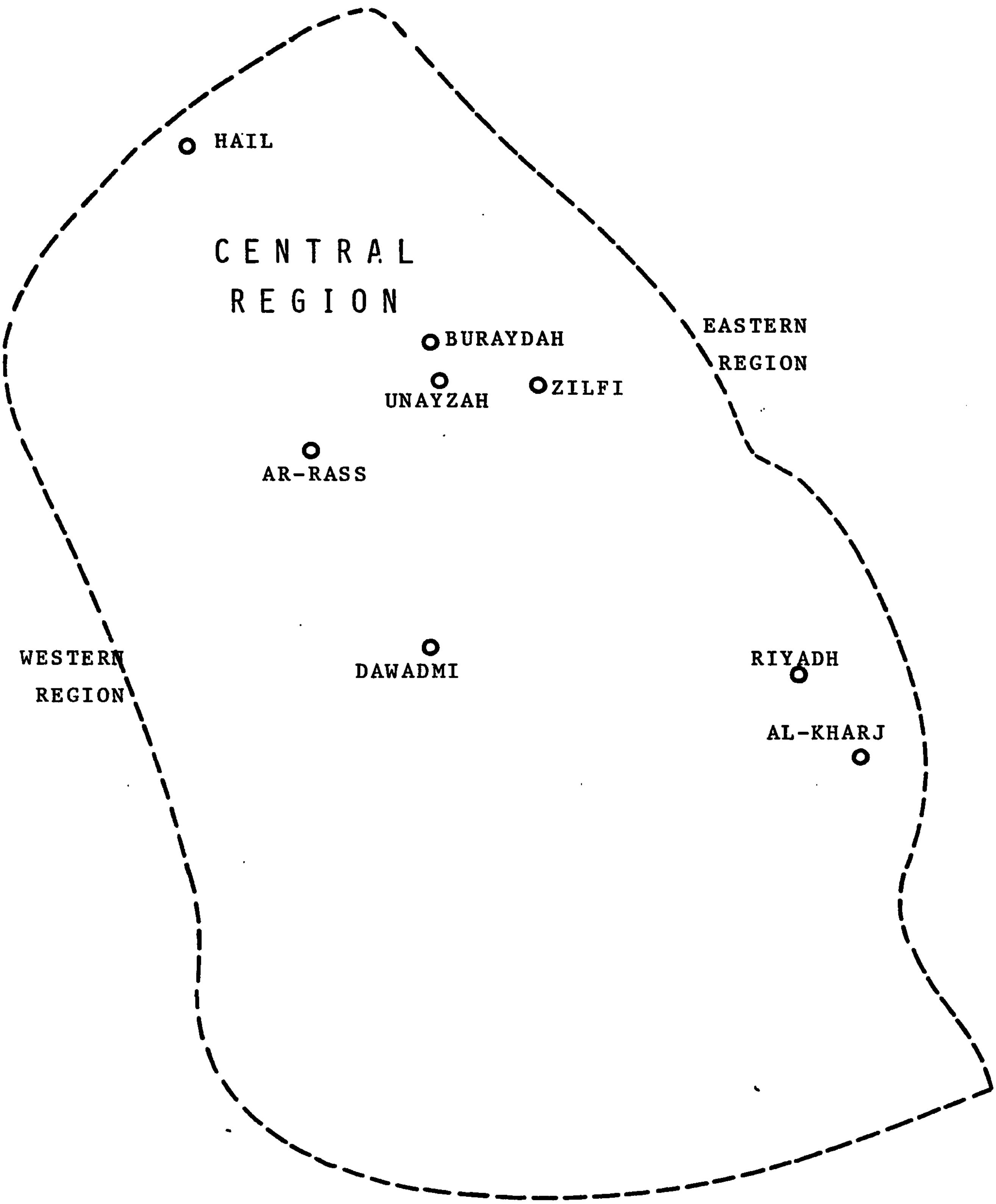


Figure 3.3. Major Electric Peak Load Location in The Central Region.

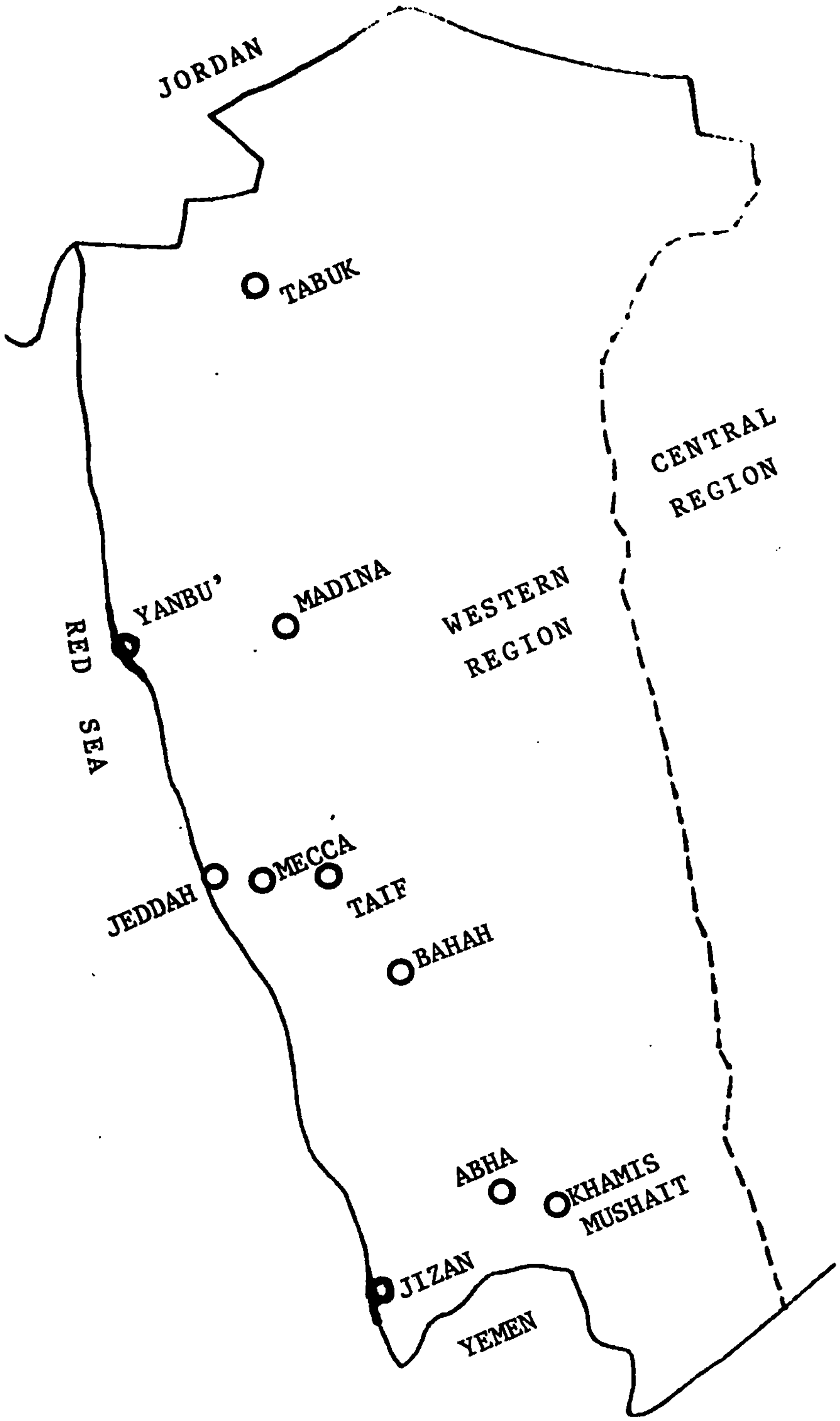


Figure 3.4. Major Electric Peak Load Location in the Western Region.

3.3. PHILOSOPHY OF THE LOAD FORECAST

3.3.1 Importance of Load Forecasting:

Electric power load forecast is the process of formulating, analyzing and evaluating alternative plans for adding to the capacity of a system to serve future loads.

The objective of power system planning is to provide utility management with sufficient information to enable decisions to be made today about the system many years in the future.

In almost all cases, planning must be done in the face of considerable uncertainty as to future loads, future equipment, installed costs, future cost of fuel, and the future cost of capital. In practice, power system planning is a complex task involving not only uncertainties, but also technical, economic constraints.

3.3.2 Forecasting Methodology:

Forecasting is simply a systematic procedure for quantitatively defining future loads. Depending on the time period of interest, a specific forecasting procedure may be classified as a short-term, intermediate, or long-term technique.

Forecasting techniques may be divided into three broad classes. Techniques may be based on extrapolation or on correlation or on a combination of both. Techniques may be further classified as either deterministic, probabilistic, or stochastic.

This Thesis contains a new method of forecasting to suit the system in the country because Saudi Arabia system is not an ordinary system in its growth due to the availability of capital and the fast growth in a short time.

3.3.3 Description of Saudi Arabia System:

Saudi Arabia, as stated before can be divided into three major regions, namely East, Centre, and West.

Each of these regions includes both large and small consumption areas. The number of households of the settled population in each of the cities, towns, and rural areas as recorded in the 1974 census (Appendix B) was one of the major basis for the non-industrial load forecast. It was then assumed that the number of households in different regions would increase at different rates and that the energy use per household would vary depending upon its location in the country as well as its size.

To forecast the peak load for the period (1979-2000), available historical data from the Ministry of Industry and Electricity are used. Such data include the peak load in the major consumption centres only during the period (1974-1978).

Information of historical peak load in smaller consumption centres is however not available. These values are estimated here and used for the projection of the overall peak load of Saudi Arabia for the coming two decades.

For these estimations several assumptions have been made. First, the Aramco peak load is assumed to be a function of its oil production, the maximum rate of oil production being taken as in the period (1986-1988), twelve million barrels/Day. During the period (1979-1986), oil production is expected to increase at a rate of half a million barrels/day. After 1988 and up to the year 2000, oil production is assumed to decrease at a rate of half a million barrel/day, reaching six million barrels/day in the year 2000. This assumption is based on the availability of oil reserves as shown in chapter II, and on the world demand requirements for the next two decades.

In 1986, oil reserves are expected to decrease, thus affecting oil production. It is obvious that the acceptability of our assumptions would depend greatly on government policy on oil production. There is however no official long range policy on this matter.

On the other hand, information for the next eight years about Al-Jubail industrial project is obtained from BECHTEL (Appendix C).

As in the above, any governmental decision changing the plans proposed by BECHTEL would greatly affect our results.

As for residential areas, they can be divided into two categories.

A - Large Consumption Centres: using population, national oil production, and peak load data for the past five years as a basis for extrapolation peak load forecasts for the coming years. These forecasts are thus predicted with a reasonable probability of occurrence.

B - Small Consumption Centres: given the lack of information on past peak load demands, estimates of future peak loads have been taken from present data from towns and villages of similar sizes.

3.3.4 Mathematical Model:

The following equations are used to determine the peak load during the period (1978-2000) for Saudi Arabia.

Let

$P_{ijK} \triangleq$ The projected peak load required for the i^{th} network in the j^{th} region at the K^{th} year.

$P_{ij0} \triangleq$ The real peak load measured in the i^{th} network at j^{th} region at the year 1978.

$F_{ijK} \triangleq$ The estimated peak load factor for the i^{th} network in the j^{th} region at the K^{th} year.

$$\therefore \quad P_{ijK} = \prod_{\ell=1}^{K} F_{ijK} \, P_{ij0}$$

For $\quad i = 1, \ldots\ldots, X$

$\qquad j = 1, \ldots\ldots, y$

The projected load for the j^{th} region at the K^{th} year.

$$P_{\bullet jK} = \sum_{i=1}^{X} P_{ijK}$$

The total projected load for Saudi Arabia at a given K^{th} year is

$$P_{\bullet\bullet K} = \sum_{j=1}^{y} P_{\bullet jK}$$

From the above equations it can be deduced that

$$P_{\bullet\bullet K} = \sum_{i=1}^{X} \sum_{j=1}^{y} \prod_{\ell=1}^{K} F_{ijK} \, P_{ij0}$$

The estimated peak load factors for the Kingdom of Saudi Arabia are shown in Table 3.1.

Different values of F_{ijK} are used according to the type of consumption area.

TABLE 3.1. The Estimated Peak Load Factors for the Kingdom of Saudi Arabia.

YEAR	EASTERN REGION			CENTRAL REGION				WESTERN REGION									
	ARAMCO	AL-JUBAIL	DEPCO & OTHERS	RIYADH	QASIM	AL-KHARJ	OTHERS	JEDDAH	MECCA	MEDINA	TAIF	YANBU'	ASIR	BAHAH	JIZAN	TABUK	OTHERS
1980	1.45	1.45*	1.50	1.60	1.60	1.50	1.25	1.60	1.40	1.40	1.40	4.0	1.79	1.50	2.0	1.55	1.33
1982	1.40	5.41*	1.45	1.60	1.40	1.50	1.25	1.60	1.40	1.40	1.40	2.5	1.20	1.33	1.50	1.50	1.25
1984	1.35	4.58*	1.40	1.45	1.40	1.40	1.20	1.45	1.30	1.30	1.30	2.0	1.33	1.25	1.33	1.45	1.20
1986	1.30	1.25*	1.35	1.40	1.20	1.40	1.20	1.40	1.30	1.30	1.30	1.75	1.13	1.20	1.25	1.40	1.17
1988	1.20	1.12	1.30	1.30	1.15	1.30	1.15	1.30	1.25	1.25	1.25	1.29	1.11	1.08	1.20	1.35	1.14
1990	1.20	1.07	1.25	1.20	1.10	1.20	1.10	1.20	1.25	1.25	1.25	1.22	1.08	1.08	1.08	1.30	1.13
1992	1.15	1.07	1.20	1.15	1.10	1.10	1.10	1.15	1.15	1.15	1.15	1.18	1.08	1.14	1.08	1.25	1.11
1994	1.15	1.07	1.15	1.15	1.05	1.05	1.05	1.15	1.15	1.15	1.15	1.15	1.07	1.06	1.07	1.20	1.10
1996	1.10	1.05	1.10	1.15	1.05	1.05	1.05	1.15	1.10	1.10	1.10	1.13	1.07	1.06	1.07	1.15	1.09
1998	1.10	1.05	1.05	1.10	1.05	1.05	1.05	1.10	1.10	1.10	1.10	1.12	1.06	1.06	1.06	1.10	1.08
2000	1.05	1.05	1.05	1.10	1.05	1.05	1.05	1.10	1.10	1.10	1.10	1.05	1.06	1.05	1.06	1.05	1.07

* BECHTEL-JUBAIL-SAUDI ARABIA, 1978.

3.4. EASTERN REGION

In the Eastern Region the Saudi Consolidated Electric Co. (SCECO) has been established by the Ministry of Industry and Electricity and given full responsibility for the generation, transmission, and sale of electric power.

Currently the Arabian American Oil Company (ARAMCO) and the Dhahran Electric Power Co. (DEPCO) make up the major portion of the SCECO transmission system. Smaller utilities located in the SCECO area including Al-Hasa and Hafr Al-Batin will be picked up and included in the interconnected system.

The peak load of ARAMCO was 322 MW in 1974. In 1975, it is decreased to 320 MW. The decrease in oil production in 1975 was responsible for the small decrease in power peak load during 1975. From this, one can conclude that the rate of increase of the peak load is a function of the oil production in ARAMCO.

Figure 3.5 shows the increase in the demand of electricity in ARAMCO since 1974. The rate of increase in 1976 was 38%, in 1977 it was 41%, and in 1978 the peak load reached 750 MW with a percentage of increase equal to 21%.

ARAMCO power system main objective was to support oil production. With the gas gathering project and other industrial projects, a new larger power generation will be required.

YEAR	ARAMCO		DEPCO & OTHERS		TOTAL EAST.	
	PEAK MW	%	PEAK MW	%	PEAK MW	%
74	322		100		422	
75	320	-0.6	154	54	474	12
76	440	38	218	42	660	39
77	620	41	320	47	940	42
78	750	21	440	38	1190	28
% OF INC.74-78		133%		340%		182%

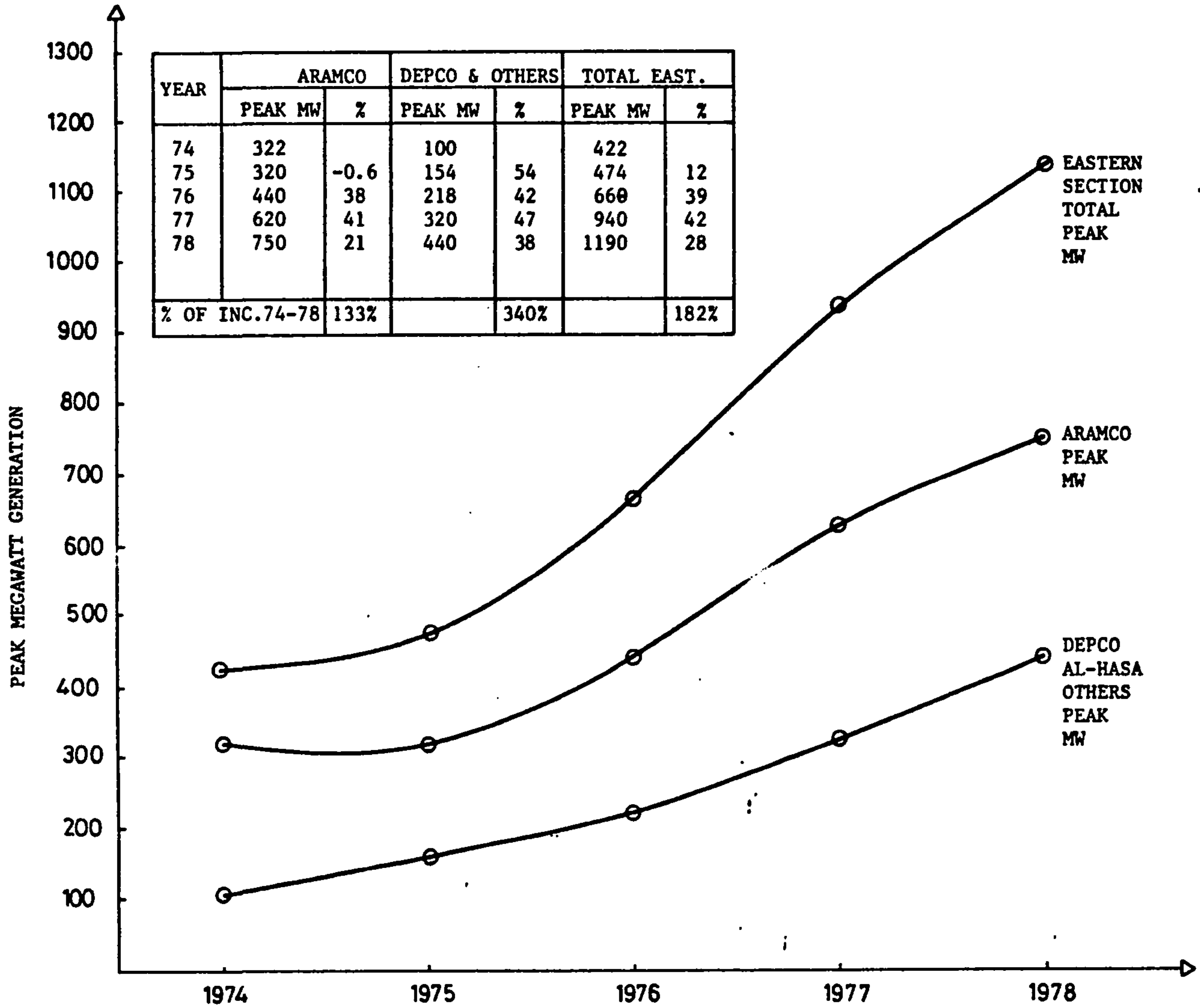


Figure 3.5. Eastern Region Peak Load Generation History (SCECO PEAK GENERATION HISTORY).

The other networks of the Eastern Region (DEPCO & AL-HASA systems with the villages in the Eastern Region) had 100 MW peak load in 1974, 218 MW in 1976 with a percentage of increase equal to 54% more than the peak load in 1975, 320 MW in 1977, and 440 MW in 1978.

The industrial peak load was equal to 8% of the total peak load in 1978 in DEPCO & AL-HASA systems.

The average annual rate of increase in the total Eastern Region demand was equal to 30% from 1974 to 1978.

From 1960 to 1978, the oil sector contributed more than 90% of the gross domestic product. Therefore, at least for the next fifteen years, the growth of the economy will be closely related to the production of crude oil.

Production of crude oil (Fig. 3.6) is expected to keep growing until 1986 to reach approximately twelve million barrels per day. After 1986, it is expected to gradually decline to reach approximately six million barrels/day in the year 2000.

Table 3.2 shows the ARAMCO estimated load during the period (1978-2000) taking into consideration that ARAMCO is an oil industry.

The new Industrial Complex in Al-Jubail will grow rapidly as indicated by a study done by BECHTEL in 1978 for The Royal

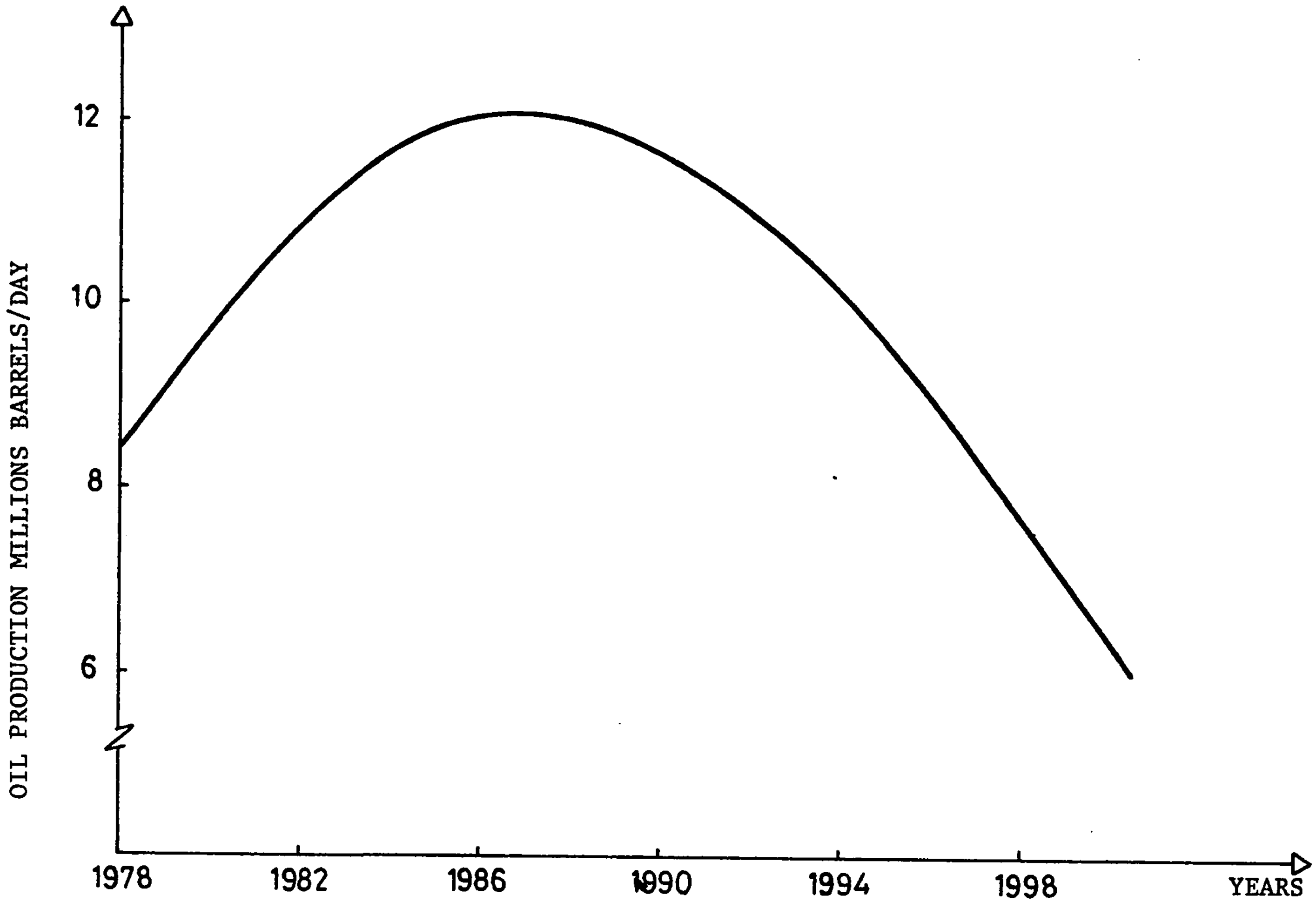


Figure 3.6. Estimate of Oil production (1978-2000).

TABLE 3.2. Aramco Peak Loads (1978-2000).

YEAR	PEAK LOAD (MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ACTUAL)	750		
1980	1,088	45	338
1982	1,523	40	435
1984	2,056	35	533
1986	2,673	30	617
1988	3,208	20	535
1990	3,850	20	642
1992	4,425	15	575
1994	5,100	15	675
1996	5,610	10	510
1998	6,150	10	540
2000	6,640	8	490

Commission of Al-Jubail (1978-1988) Appendix C. The MW demand in Al-Jubail is shown in Table 3.3.

The non ARAMCO networks of the Eastern Region will continue to increase due to the development of new industrial complexes. Figure 3.5 shows that the peak load in this system was 100 MW in 1974, and reached 440 MW in 1978. In the year 2000 the load will be ten times as much as the load in 1978. Table 3.4 shows the MW peak demand during the period (1978-2000).

The total power demand of all Eastern Region will grow with such a large rate because of the following reasons:

A - The yearly rate of increase of population will be approximately 8-10%.

B - The rate of oil production and oil availability will increase up to the year 1986 and then decrease.

C - Gas gathering program will start.

D - The new industrial complex in Al-Jubail will start (the largest in Saudi Arabia).

TABLE 3.3. Jubail Industry Peak Loads (1978-2000).

YEAR	PEAK LOAD (MW)	% OF INCREASE	MW REQUIRED ADDITION
1978	60		
1980	98	63	38
1982	530	441	432
1984	2,430	358	1,900
1986	3,044	25	614
1988	3,400	12	356
1990	3,638	7	238
1992	3,890	7	252
1994	4,160	7	270
1996	4,370	5	210
1998	4,590	5	220
2000	4,820	5	230

TABLE 3.4. DEPCO & AL-HASA & Other Eastern Region Peak Loads (1978-2000).

YEAR	PEAK LOAD(MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ACTUAL)	440		
1980	660	50	220
1982	957	45	297
1984	1,340	40	383
1986	1,810	35	470
1988	2,350	30	540
1990	2,930	25	580
1992	3,510	20	580
1994	4,040	15	530
1996	4,450	10	410
1998	4,670	5	220
2000	4,900	5	230

E - Oil refining will increase to meet the oil demand in Saudi Arabia.

F - Construction of a new air base and a new garrison city (King Khalid Military City) in the Region will be completed.

G - Connection of the Central Region with the Eastern Region System would require delivery of more electricity to the Central Region.

Table 3.5 shows the total requirement of electricity during the period (1978-2000) in the Eastern Region. Figure 3.7 shows the total requirement of electricity from 1978 to the year 2000 for the Eastern Region.

3.5. CENTRAL REGION

The largest system in the Central Region is that of the Riyadh Electric Company which supplies Riyadh and its suburbs.

TABLE 3.5. Total Eastern Region Peak Loads (1978-2000).

YEAR	PEAK LOAD (MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ACTUAL)	1,190		
1980	1,846	55	656
1982	3,019	63	1,164
1984	5,826	94	2,816
1986	7,527	29	1,701
1988	8,958	19	1,431
1990	10,418	16	1,460
1992	11,825	14	1,407
1994	13,300	12	1,475
1996	14,430	8	1,130
1998	15,410	7	980
2000	16,360	6	950

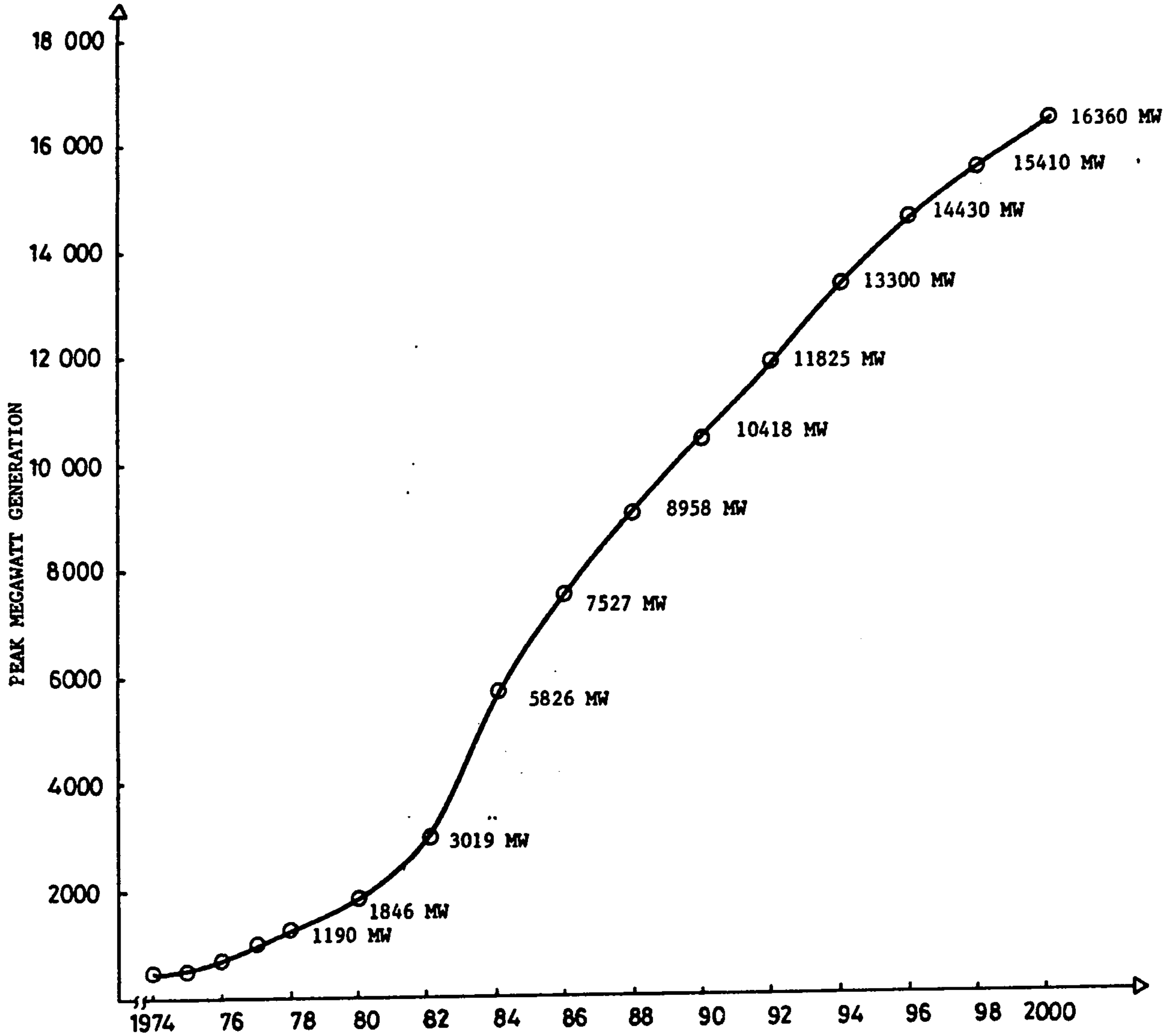


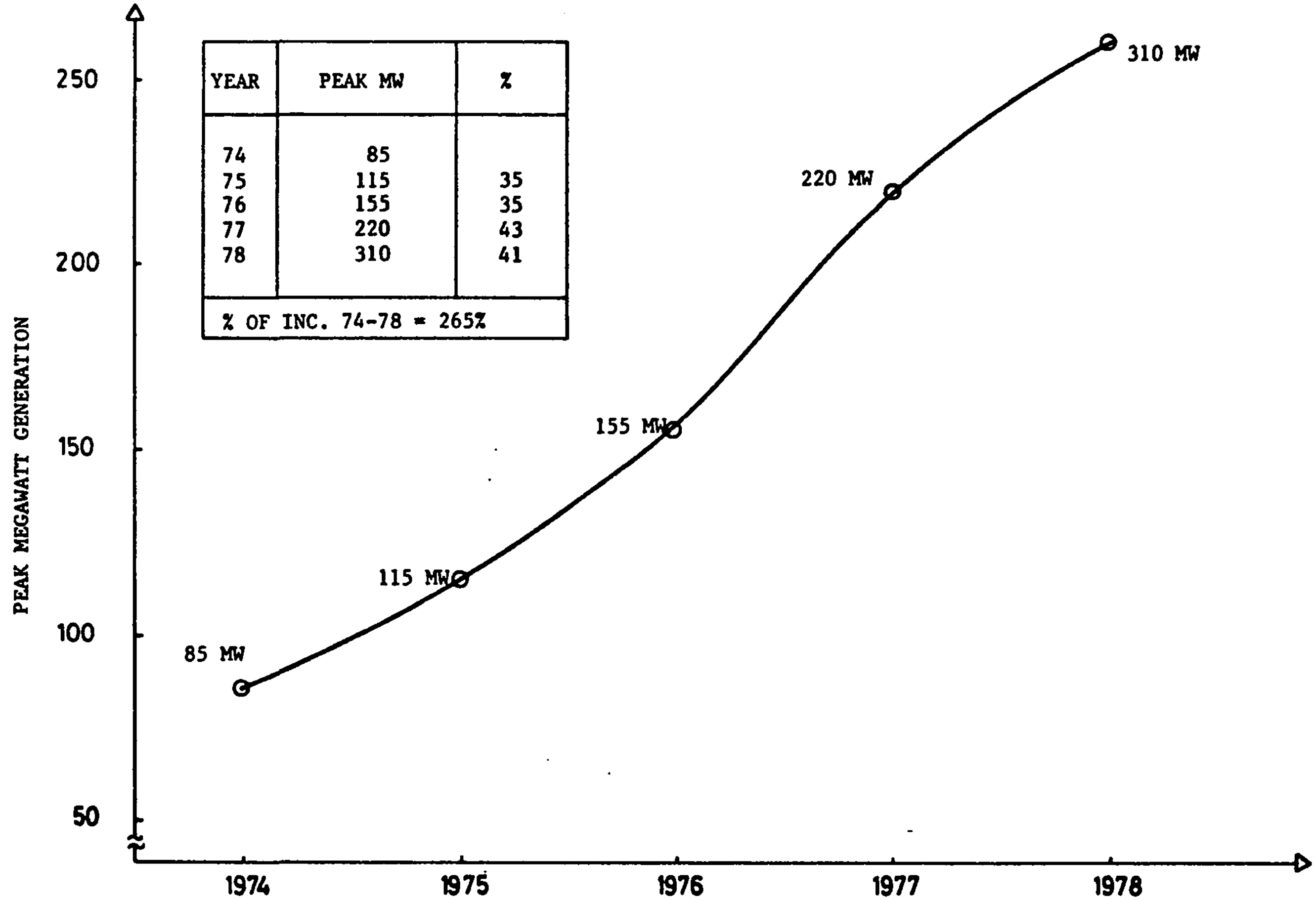
Figure 3.7. The total peak MW requirement in the Eastern Region of Saudi Arabia (1974-2000).

North of Riyadh in the province of Qasim is the city of Buraydah, which has the only other major system in the Central Region. All the other load areas are currently served by local diesel generators with low voltage distribution and no significant transmission.

3.5.1 Riyadh:

The peak load of Riyadh (Fig. 3.8) was equal to 85 MW in 1974. In 1975 it reached 115 MW with an increase of 35%. The rate of increase was 35% in 1976, and 43% in 1977. In 1978 the peak load reached 310 MW with a rate of increase equal to 41%. The industrial peak load in Riyadh equalled 10% the total load in 1978. The average yearly rate of increase of electric demand in Riyadh was equal to 40% from 1974 to 1978.

The Riyadh electric system will continue to increase because Riyadh population increases at a rate higher than that of any other city in the country. Most of the government ministries and agencies are in Riyadh. The rate of the industrial load will stay in the range of 10% because of the inadequate location of Riyadh in this respect and of the scarcity of water.



YEAR	PEAK MW	%
74	85	
75	115	35
76	155	35
77	220	43
78	310	41
% OF INC. 74-78 = 265%		

Figure 3.8. Riyadh peak generation history.

Table 3.6 shows the MW peak demand during the period (1978-2000) for Riyadh.

The base load of Riyadh will start to be supplied from the Eastern Region in the year 1982. By the year 2000, about one third of Riyadh load will be supplied by the Eastern Region generation.

3.5.2 Qasim:

Figure 3.9 shows the increase in the peak load in two major cities in Al-Qasim, Buraida and Unayza. The total peak load was 20 MW in 1978, from 5.2 MW in 1974. The high rate of increase in electric demand is due to the increasing needs of the people living in the area and to the rising living standards.

The total peak loads of small villages of the area of Al-Qasim could be estimated at no more than 5 MW in 1978.

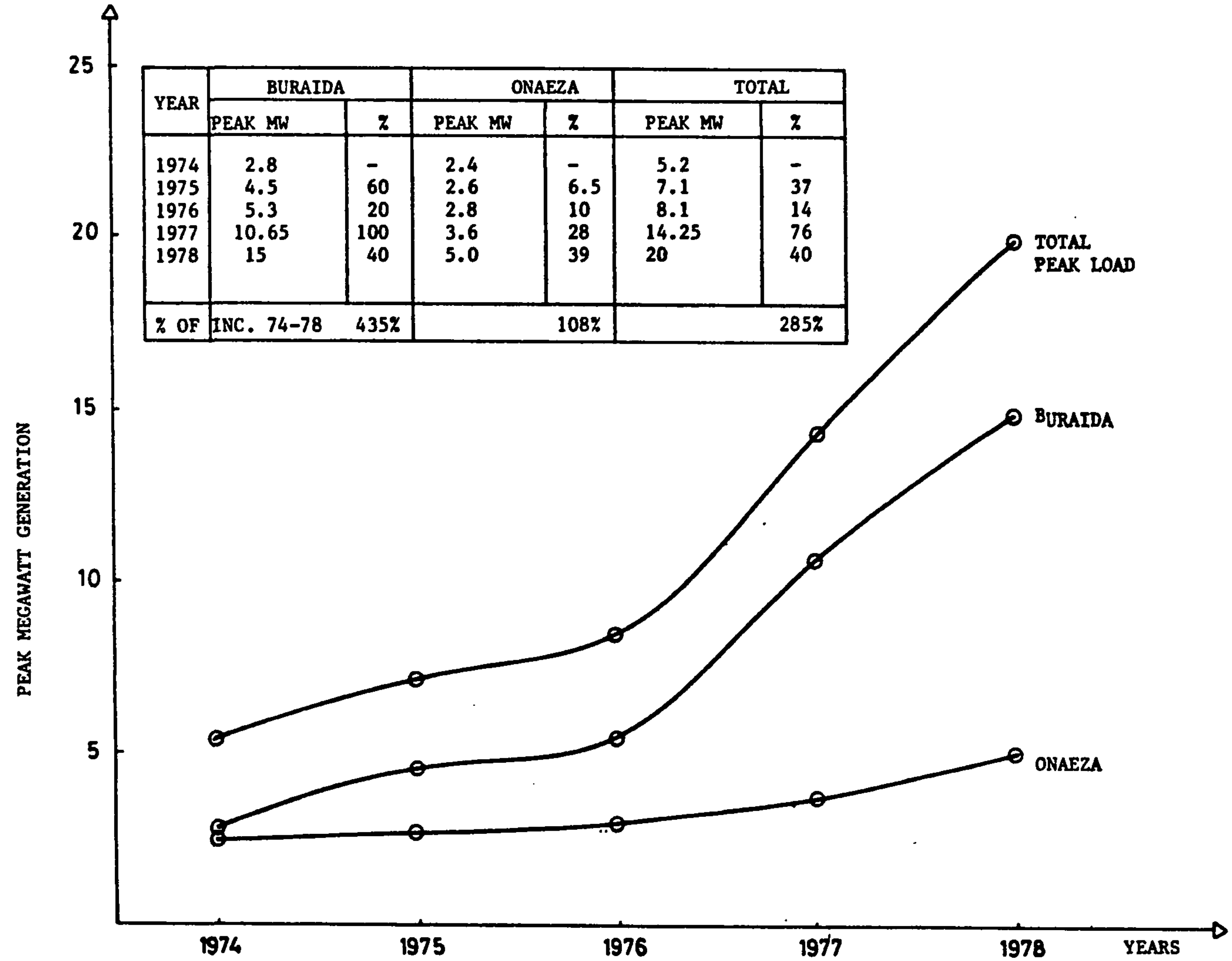
Table 3.7 shows the total load of Al-Qasim for the period (1978-2000).

3.5.3 Al-Kharj:

This city is 80 km south of Riyadh with the population in 1974 equal to 43,000 people. There are small villages around this city in need of electricity albeit in smaller amounts.

TABLE 3.6. Riyadh Peak Load (1978-2000).

YEAR	PEAK LOAD (MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ACTUAL)	310		
1980	500	61.29	190
1982	800	60	300
1984	1,160	45	360
1986	1,624	40	464
1988	2,110	30	486
1990	2,530	20	420
1992	2,910	15	380
1994	3,350	15	440
1996	3,850	15	500
1998	4,240	10	390
2000	4,660	10	420



YEAR	BURAIDA		ONAEZA		TOTAL	
	PEAK MW	%	PEAK MW	%	PEAK MW	%
1974	2.8	-	2.4	-	5.2	-
1975	4.5	60	2.6	6.5	7.1	37
1976	5.3	20	2.8	10	8.1	14
1977	10.65	100	3.6	28	14.25	76
1978	15	40	5.0	39	20	40
% OF	INC. 74-78	435%		108%		285%

Fig. 3.9. Buraida, Onaeza peak generation history.

TABLE 3.7. Al-Qasim Peak Load (1978-2000).

YEAR	PEAK LOAD (MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ESTIMATED)	25		
1980	40	60	15
1982	56	40	16
1984	78	40	22
1986	94	20	16
1988	108	15	14
1990	120	10	12
1992	132	10	12
1994	140	5	8
1996	147	5	7
1998	155	5	8
2000	162	5	7

With the load in 1978 estimated at 10 MW leads to the expected need of this area until the year 2000 as shown in Table 3.8.

3.5.4 Other Loads in the Central Region:

Most of the other loads in the Central Region concentrate in Al-Majmaah, Hail, Al-Zulfi, Shaqra, Hawtat Beni Tamim, Al-Aflaj, Al-Sulayyil, Wadi Ad-Dawaser, Ad-Dawadmi, Afif and Al-Rass.

The total peak in 1978 was estimated to be 50 MW. Table 3.9 shows the need of electricity for the scattered loads of the Central Region in the period (1978-2000).

From the above it may be concluded that the connection to the Riyadh system of Al-Qasim in 1984 and Al-Kharj in 1983 are both needed. But the other loads in the Central Region, should have their own generation because of their small loads requirement, and their geographical dispersion.

3.5.5 Fuel Supply:

The required crude oil fuel for the local generation will be supplied from the Eastern Region through two means:

First : From Khurais 200 km east of Riyadh by pipeline.

Second : East-West pipeline from Abqaiq in the Eastern Region to Yanbu' in the Western Region through Al-Qasim.

TABLE 3.8. Al-Kharj Peak Load (1978-2000).

YEAR	PEAK LOAD (MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ESTIMATED)	10		
1980	15	50	5
1982	22.5	50	7.5
1984	31.5	40	9
1986	44	40	12.5
1988	57	30	13
1990	68	20	11
1992	75	10	7
1994	79	5	4
1996	83	5	4
1998	87	5	4
2000	92	5	5

TABLE 3.9. Other Loads in the Central Region (1978-2000).

YEAR	PEAK LOAD (MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ESTIMATED)	50		
1980	62.5	25	12.5
1982	78	25	15.5
1984	94	20	16
1986	112	20	18
1988	130	15	18
1990	142	10	12
1992	156	10	14
1994	165	5	9
1996	172	5	7
1998	181	5	9
2000	190	5	9

The first one will supply Riyadh Refinery with crude oil and also part of the generation requirement. After 1988 most of the generation in Riyadh should be able to use fuel oil or diesel.

On the other hand Al-Qasim will continue using diesel fuel until gas and crude oil become available from the East-West pipe line in 1984. It is also possible to supply Al-Qasim either by fuel oil or diesel fuel through Riyadh Refinery.

3.5.6 Total Peak Load in the Central Region:

Table 3.10 and Fig. 3.10 show the total electric power requirement for the Central Region of Saudi Arabia until the year 2000.

The total peak load for the Eastern and Central Regions of Saudi Arabia are summarized in Table 3.11.

3.6. WESTERN REGION

In the Western Region the present transmission systems are centered around the load centres of Jeddah, Mecca, Taif, and Medina. They are under the jurisdiction of the Saudi National Electric Company. In addition the construction of desalination facilities by the Saline Water Conversion Corporation (SWCC) at Jeddah and Yanbu' will make available in the early 1980's 640 MW to the various load centres. As a result the Ministry of

TABLE 3.10. Central Region Peak Load (1978-2000).

YEAR	PEAK LOAD(MW)	% OF INCREASE	MW REQUIRED ADDITION
1978	395		
1980	617.5	56	222
1982	956.5	55	339.5
1984	1,363.5	43	407
1986	1,874	37	510.5
1988	2,405	28	531
1990	2,860	19	455
1992	3,273	14	413
1994	3,734	14	461
1996	4,252	14	518
1998	4,663	10	411
2000	5,104	9	441

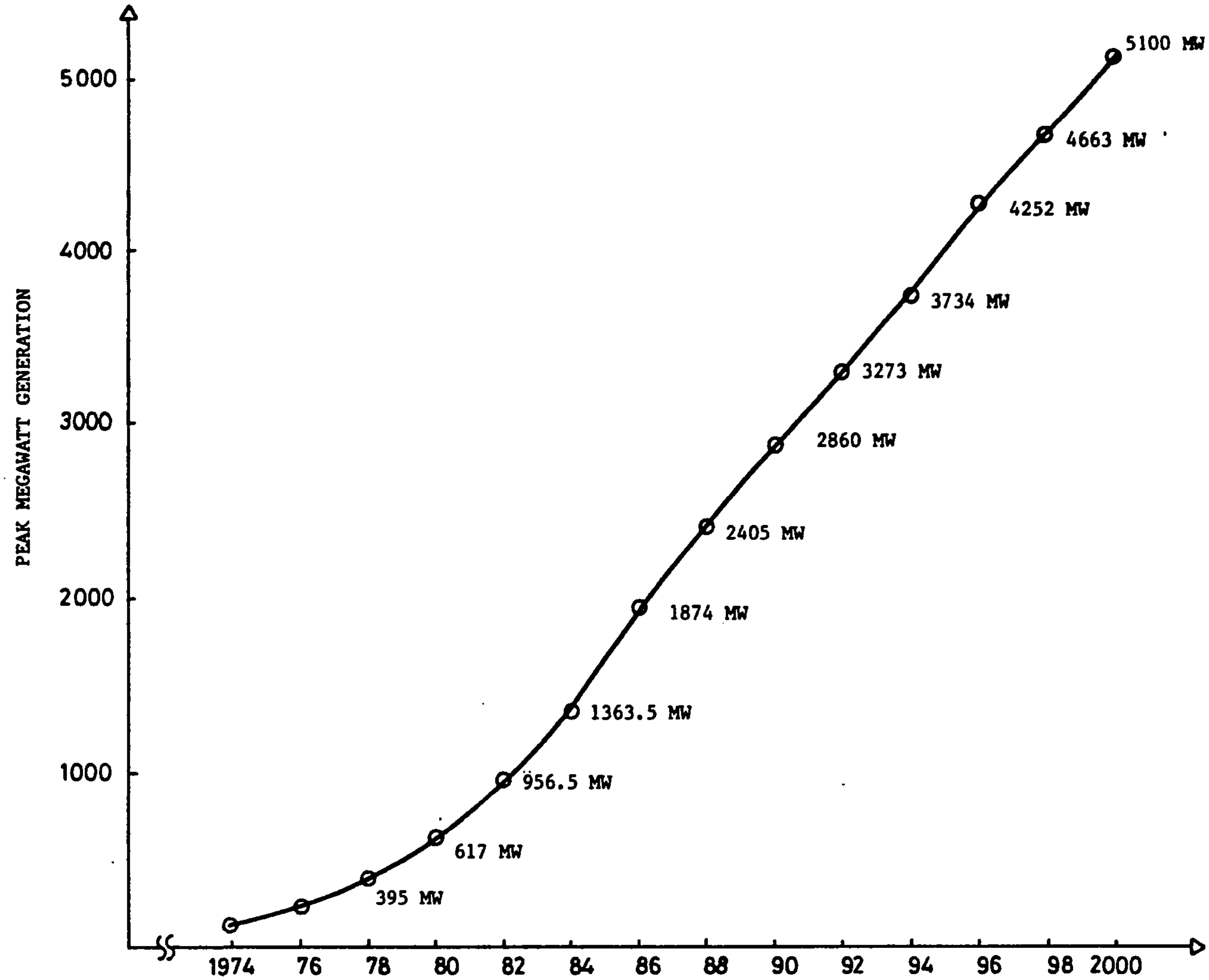


Figure 3.10. The total peak MW requirement for the Central Region (1974-2000).

TABLE 3.11. Total Peak Load for the Eastern & Central Regions of Saudi Arabia (1978-2000).

YEAR	PEAK LOAD (MW)		
	EASTERN REGION	CENTRAL REGION	TOTAL
1978	1,190	395	1,585
1980	1,846	617	2,463
1982	3,010	956.5	3,966.5
1984	5,826	1,363.5	7,189.5
1986	7,527	1,874	9,401
1988	8,958	2,405	11,363
1990	10,418	2,860	13,278
1992	11,825	3,273	15,098
1994	13,300	3,734	17,034
1996	14,430	4,252	18,682
1998	15,410	4,663	20,073
2000	16,360	5,104	21,464

Industry and Electricity has recently decided to build a 230 KV transmission line from Jeddah to Mecca, and another from Yanbu' to Medina. This transmission system, when completed, will interconnect the Jeddah, Mecca, Medina, Taif, Yanbu', SWCC - Medina (at Yanbu') and SWCC-Jeddah systems. The first line of this system will be between Jeddah and Mecca and is expected to be in service by 1981.

The census of 1974 shows that the population of the Western Region is the largest in the country |Appendix B|. Table 3.12 shows the population in the major cities in the Western Region arranged in decreasing numbers. Also Fig. 3.11 shows the historical peak load of Jeddah, Mecca, Taif and Medina. Figure 3.12 shows the historical peak load of Khamis Mushayt and Tabuk since 1974. It is found that the peak load in these cities is a function of the size of the population. The projection of each important centre of population will be taken separately and the final results will be added.

3.6.1 Jeddah:

Jeddah is growing very rapidly. In 1974, the peak load of Jeddah was 91 MW. In 1975, it reached 132 MW with a yearly increase of 45%. The yearly rate of increase was 22% in 1976 and 56% in 1977. In 1978 the peak load reached 348 MW with a yearly percentage of increase equal to 39%.

The rate of increase in Jeddah is comparable to that of Riyath.

TABLE 3.12. Major Cities of Western Region Arranged by Number of Population, 1974.*

MAJOR CITIES	NO. OF POPULATION
Jeddah	561,104
Mecca	366,801
Taif	204,857
Medina	198,186
Tabuk	74,825
Khamis Mushayt	49,581
Jazan	32,812
Abha	30,150

* Official Census figures -(Appendix B.)

YEAR	MEDINA PEAK MW	MEDINA %	TAIF PEAK MW	TAIF %	MECCA PEAK MW	MECCA %	JEDDAH PEAK MW	JEDDAH %	TOTAL PEAK MW	TOTAL %
74	15		14		40		91		160	
75	17.5	17	19	36	48.5	21	132	45	217	36
76	20	15	23	22	58	20	161	22	262	21
77	27	37	29	12	68	19	251	56	375	43
78	35	30	36	24	81.5	20	348	39	500	33
%OF INCREASE (1974-78)		133		157		104		283		213

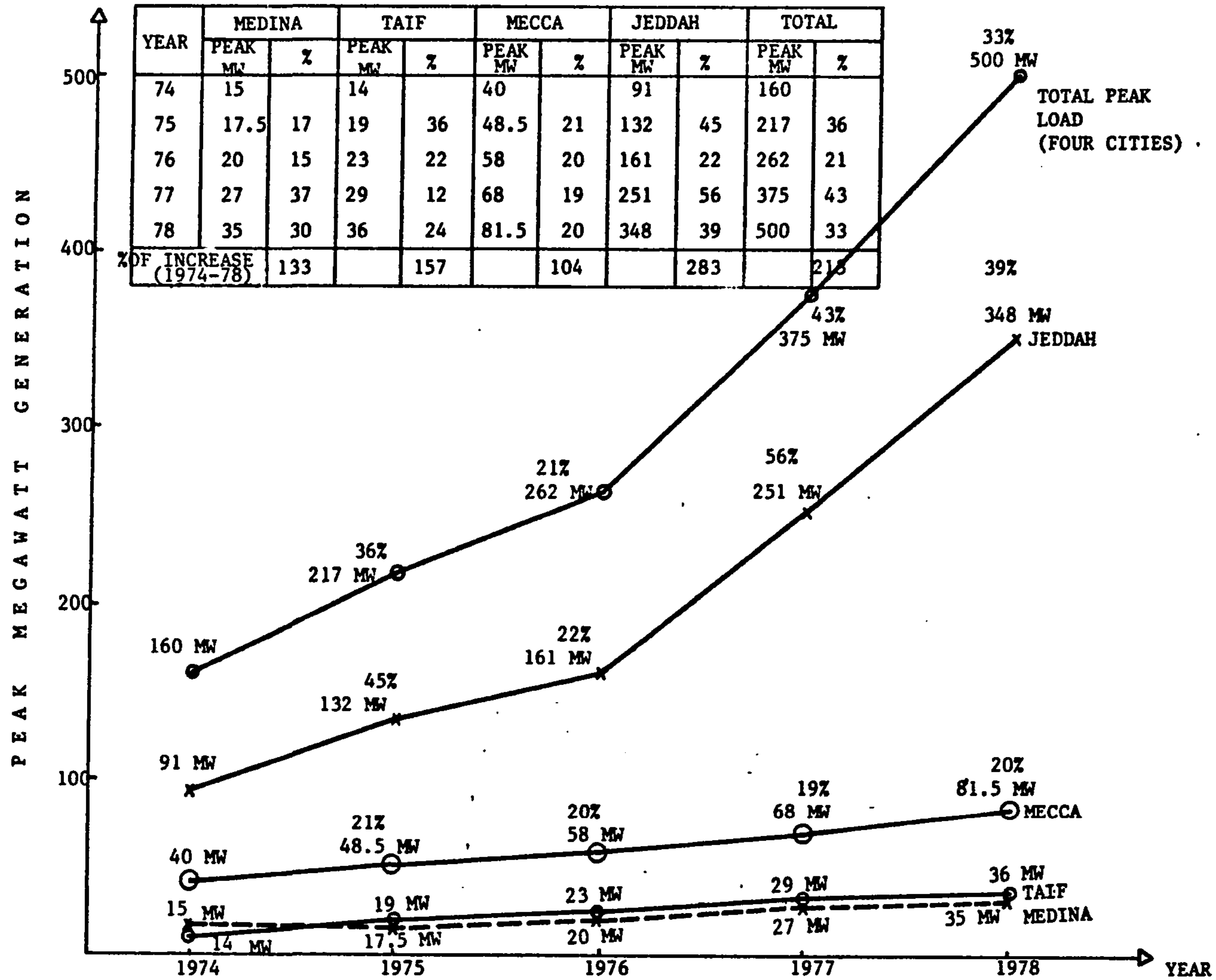


Figure 3.11. Peak Generation History for Jeddah, Mecca, Taif and Medina.

YEAR	TABUK		KHAMIS MUSHAYT	
	PEAK MW	%	PEAK MW	%
74	0.5	480	2.3	
75	2.9	480	3.5	52
76	3.3	14	4.9	40
77	4.0	22	6	23
78	5.5	38	7.5	25
% OF INC. 74-78		1000%		226%

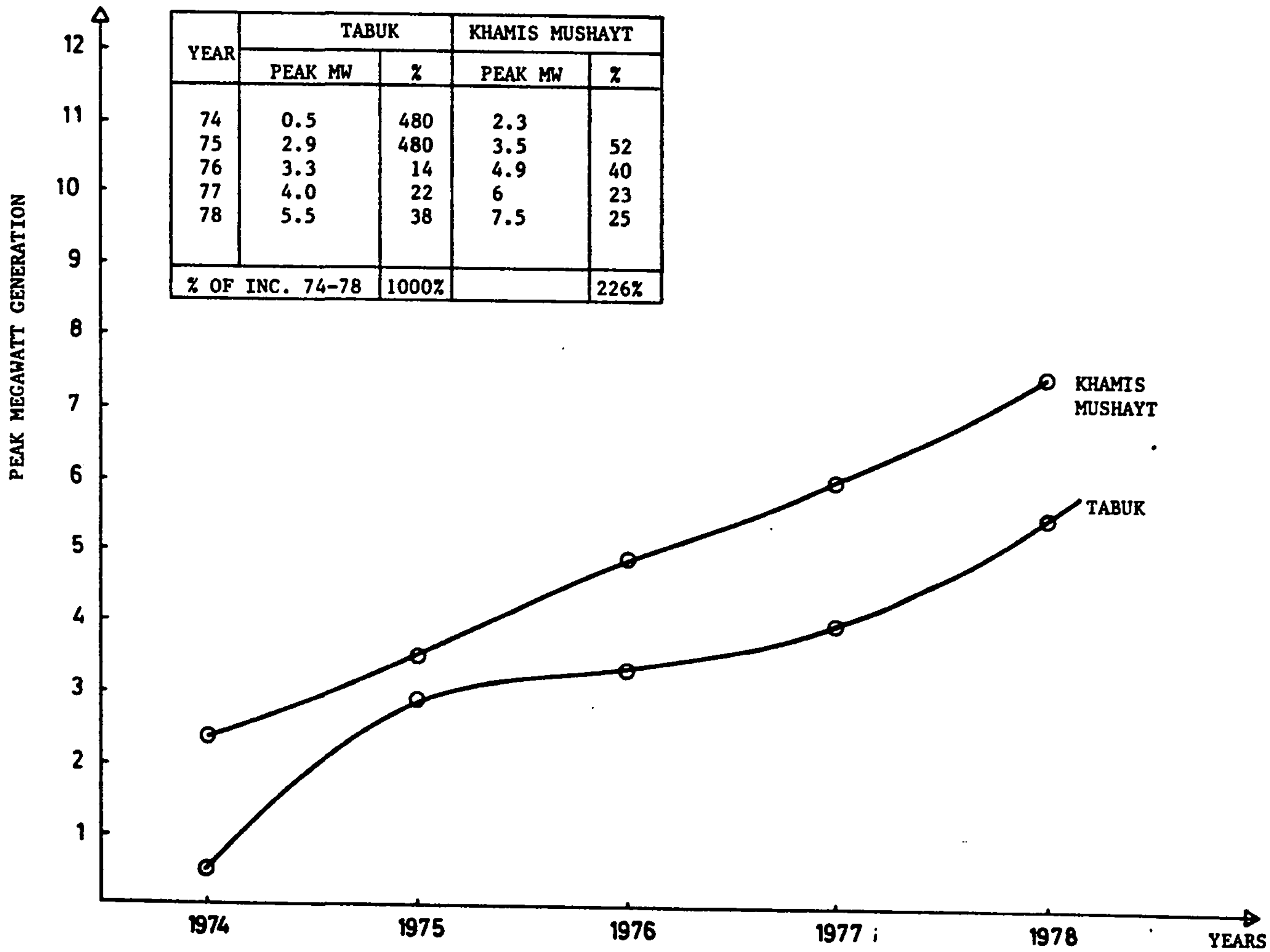


Figure 3.12. Khamis Mushayt & Tabuk peak generation.

In 1978, the industrial peak load in Jeddah was equal to 2.5% of the total peak. Jeddah system will continue to increase because the city is the commercial centre of Saudi Arabia, and its population increases with a yearly rate of 8-10%. Table 3.13 shows the MW peak demand during the period (1978-2000).

3.6.2 Mecca:

Figure 3.11 shows the increase in the peak load of Mecca. The peak load in 1978 was 81.5 MW, while in 1974 it was only 50 MW. Mecca is not an industrial city and the yearly rate of increase of its electric demand is lower than those of the other large cities of Saudi Arabia. Table 3.14 shows the total peak load of Mecca for the period (1978-2000).

3.6.3 Medina:

Figure 3.11 shows the increase in the peak load of Medina. The peak load in 1978 was 35 MW, and 15 MW only in 1974. Although, Medina is a holy city for all the Muslims of the world, it is not an industrial area. The yearly average rate of increase of electric load was 30% during the last five years. In 1975 it was 17% only. In 1976 the peak load was 20 MW with a percentage of increase of 15%, reaching 37% in 1977.

Table 3.12 shows that in 1974, the population of Medina reached 198,186. It is about half the population of Mecca. Table 3.15 shows the total peak load of Medina for the period (1978-2000).

TABLE 3.13. Jeddah Peak Load (1978-2000).

YEAR	PEAK LOAD (MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ACTUAL)	348		
1980	557	60	209
1982	890	60	333
1984	1,292	45	402
1986	1,808	40	516
1988	2,351	30	543
1990	2,821	20	470
1992	3,244	15	423
1994	3,730	15	486
1996	4,290	15	560
1998	4,720	10	430
2000	5,200	10	480

TABLE 3.14. Mecca Peak Load (1978-2000).

YEAR	PEAK LOAD(MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ACTUAL)	81.5		
1980	114	40	32.5
1982	160	40	46
1984	207	30	47
1986	270	30	63
1988	337	25	67
1990	422	25	85
1992	485	15	63
1994	558	15	73
1996	612	10	54
1998	675	10	63
2000	743	10	68

TABLE 3.15. Medina Peak Load (1978-2000).

YEAR	PEAK LOAD(MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ACTUAL)	35		
1980	50	40	15
1982	70	40	20
1984	91	30	21
1986	119	30	28
1988	148	25	29
1990	185	25	37
1992	213	15	28
1994	245	15	32
1996	269	10	24
1998	296	10	27
2000	326	10	30

3.6.4 Taif:

During the last five years (1974-1978), Taif kept a peak load similar to those of Medina. The peak load projection for Taif will also be similar to that of Medina for the period (1978-2000). Table 3.16 shows the peak load for Taif for the period (1978-2000).

3.6.5 Yanbu':

Yanbu' is a small town on the Red Sea, north of Jeddah. It will soon be the site of a large industrial complex as well as a refinery. Thus, the growth rate of the electric demand will be very large. In 1978, the load was estimated to be 10 MW. It is expected to reach 1000 MW in the year 2000. Table 3.17 shows the growth in electric needs in Yanbu'.

3.6.6 Asir Province:

The two principal towns of Asir, are Abha and Khamis Mushait. Abha, which is centrally located in the province, is the administration center. It has a population of approximately 30,000. Khamis Mushait has about 50,000 inhabitants. The rest of the population of Asir amounts to about 214,000 people living scattered in about 13,000 rural households. They are primarily engaged in farming and depend largely on the relatively high rainfall. Figure 3.12 shows the increase in the load in Khamis Mushait which is the largest load center of Asir. The rate of increase is about 30%. The load in Abha was estimated to be 6 MW

TABLE 3.16. Taif Peak Load (1978-2000).

YEAR	PEAK LOAD(MW)	% OF INCREASE	MW REQUIRED ADDITION
1978	36		
1980	51	40	15
1982	71	40	20
1984	92	30	21
1986	120	30	28
1988	150	25	30
1990	190	25	40
1992	215	15	25
1994	250	15	35
1996	270	10	20
1998	300	10	30
2000	330	10	30

TABLE 3.17. Yanbu' Peak Load (1978-2000).

YEAR	PEAK LOAD(MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ESTIMATED)	10		
1980	40	300	30
1982	100	150	60
1984	200	100	100
1986	350	75	150
1988	450	29	100
1990	550	22	100
1992	650	18	100
1994	750	15	100
1996	850	13	100
1998	950	12	100
2000	1,000	5	50

in 1978. The requirement of electric power for this area until the year 2000 is shown in Table 3.18.

3.6.7 Bahah Province:

The two principal towns are Bahah and Biljurshi. Bahah, which is centrally located within the province, is the administration center with approximately 32,000 inhabitants. Biljurshi is larger than Bahah with a population of 40,000.

The remaining population is 80,000. The inhabitants are primarily engaged in farming and depend on the high rainfall of the area. The peak load was estimated to be 20 MW in 1978. The requirement of electric power for this area during the period (1978-2000) is shown in Table 3.19.

3.6.8 Jizan Province:

Jizan is in the South-Western Region and lies in the low flat country to the west of the irrigation dam which serves the Wadi Jizan basin. There are three main towns, Jizan, Abu Arish and Sabya.

Jizan which is the largest city, is also a small sea port on the Red Sea and has a population of approximately 32,000.

The estimated peak load in 1978 was 10 MW. It will reach 35 MW in 1984, and 65 MW in 2000. Table 3.20 shows the expected growth in Jizan Province during the period (1978-2000).

TABLE 3.18. Asir Province Peak Load (1978-2000).

YEAR	PEAK LOAD(MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ESTIMATED)	28		
1980	50	79	22
1982	60	20	10
1984	80	33	20
1986	100	13	10
1988	110	11	10
1990	120	8	10
1992	130	8	10
1994	140	7	10
1996	150	7	10
1998	160	6	10
2000	170	6	10

TABLE 3.19. Bahah Province Peak Load (1978-2000).

YEAR	PEAK LOAD(MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ESTIMATED)	20		
1980	30	50	10
1982	40	33	10
1984	50	25	10
1986	60	20	10
1988	65	8	5
1990	70	8	5
1992	80	14	10
1994	85	6	5
1996	90	6	5
1998	95	6	5
2000	100	5	5

TABLE 3.20. Jizan Province Peak Load (1978-2000).

YEAR	PEAK LOAD(MW)	% OF INCREASE	MW REQUIRED ADDITION
1978	10		
1980	20	100	10
1982	30	50	10
1984	40	33	10
1986	50	25	10
1988	60	20	10
1990	65	8	5
1992	70	8	5
1994	75	7	5
1996	80	7	5
1998	85	6	5
2000	90	6	5

3.6.9 Tabuk Province & the Northern Borders:

The city of Tabuk is approximately 500 km North of Medina with a population of 74,000 people in 1974. There are small villages and towns around this city in need of electricity.

In 1978 the estimated load of Tabuk Province and Northern Borders was 30 MW. Table 3.21 shows the need of this area until the year 2000.

3.6.10 Other Small Loads in the Western Region:

There are small loads in different towns and villages not included in the previous areas. They are estimated to be 40 MW in 1978. Table 3.22 shows the expected growth in these small villages and isolated area.

3.6.11 Fuel Supply:

The local generation will be supplied in 1984 with fuel from the Eastern Province through an East-West pipeline. Until then, ships are the most economical way to supply fuel to the Western Region. It may be possible to continue supplying fuel by ships to areas far from Yanbu' (such as Jizan) and then through pipe line or trucks to Abha.

3.6.12 Total Peak Load in the Western Region:

The total peak load for the Western Region is shown in Table 3.23.

TABLE 3.21. Tabuk Province and Northern Borders Peak Load (1978-2000).

YEAR	PEAK LOAD(MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ESTIMATED)	30		
1980	47	55	17
1982	70	50	23
1984	102	45	32
1986	142	40	40
1988	192	35	50
1990	250	30	58
1992	312	25	62
1994	375	20	63
1996	430	15	55
1998	475	10	45
2000	500	5	25

TABLE 3.22. Other Small Loads in the Western Region (1978-2000).

YEAR	PEAK LOAD(MW)	% OF INCREASE	MW REQUIRED ADDITION
1978(ESTIMATED)	40		
1980	52	33	12
1982	65	25	13
1984	78	20	13
1986	92	17	14
1988	105	14	13
1990	118	13	13
1992	131	11	13
1994	145	10	14
1996	158	9	13
1998	170	8	12
2000	182	7	12

TABLE 3.23. Total Peak Load for the Western Region (1978-2000).

YEAR	PEAK LOAD(MW)	% OF INCREASE	MW REQUIRED ADDITION
1978	638.5		
1980	1,011	58	372.5
1982	1,556	54	545
1984	2,232	43	676
1986	3,111	39	879
1988	3,968	28	857
1990	4,791	21	823
1992	5,530	15	739
1994	6,353	15	823
1996	7,199	13	846
1998	7,926	10	727
2000	8,641	9	715

3.7. TOTAL PEAK LOAD FOR SAUDI ARABIA

Table 3.24 and Fig. 3.13 show the total peak MW requirement in Saudi Arabia during the period (1978-2000).

3.8. COMPARISON BETWEEN THIS STUDY AND C.T. MAIN STUDY

C.T. Main did in 1977 a load forecast for Saudi Arabia. Recognizing the fact that forecasts should be updated frequently, the study in this report is an attempt to forecast the peak load for Saudi Arabia using assumptions independent of these used in the C.T. Main study.

The following is a comparison between the two studies:

1) Eastern Region:

Table 3.25 and Fig. 3.14 show the comparison of the peak MW between this study |study A| and C.T. Main study |study B|.

It results that estimates of |A| for the peak load until the year 2000 are higher than those of |B| because depended on information obtained in 1975, while |A| used 1978 data. In 1975 there was no information about Al-Jubail industrial complex. In 1978, the actual peak load in the Eastern Region was 1190 MW but |B| assumed it to be 1567 MW with an error of 32%, and that is why

TABLE 3.24. Total Peak Load for the Kingdom of Saudi Arabia (1978-2000).

YEAR	PEAK MW GENERATION REQUIREMENT			
	EASTERN REGION	CENTRAL REGION	WESTERN REGION	TOTAL SAUDI ARABIA
1978	1,190	395	638.5	2,223.5
1980	1,846	617	1,011	3,474
1982	3,010	956.5	1,556	5,522.5
1984	5,826	1,363.5	2,232	9,421.5
1986	7,527	1,874	3,111	12,512
1988	8,958	2,405	3,968	15,331
1990	10,418	2,860	4,791	18,069
1992	11,825	3,273	5,530	20,628
1994	13,300	3,734	6,353	23,387
1996	14,430	4,252	7,199	25,881
1998	15,410	4,663	7,926	27,999
2000	16,360	5,104	8,641	30,105

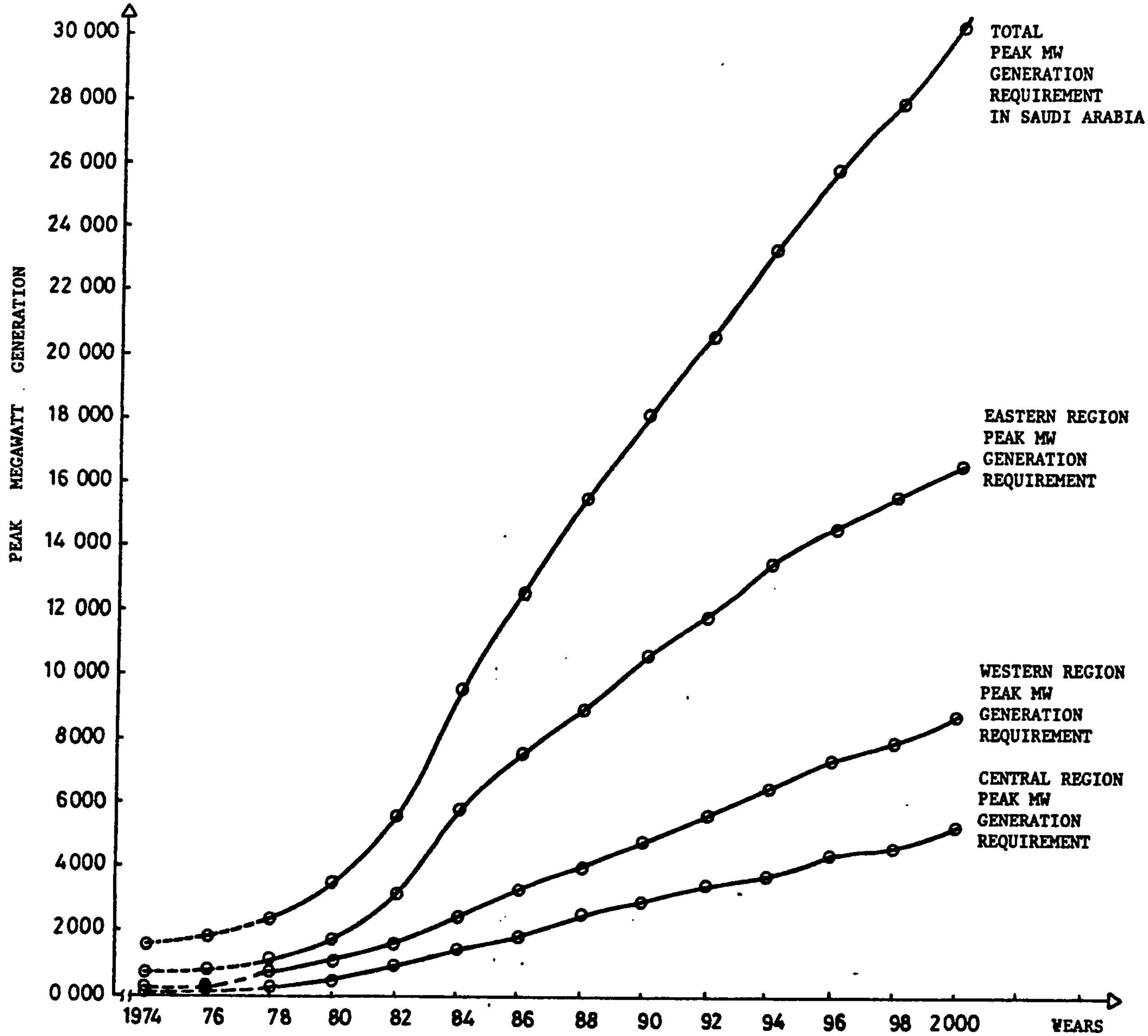


Figure 3.13. The total peak MW requirement in Saudi Arabia (1974-2000).

TABLE 3.25. Comparison of the Peak MW Between |A| and |B| for the Eastern Region.

YEAR	STUDY |A|		STUDY |B|
1978	1190	|Actual|	1567
1980	1846		2169
1982	3010		3170
1984	5826		4534
1986	7527		5737
1988	8959		7887
1990	10418		8480
1992	11825		9145
1994	13300		9753
1996	14430		10281
1998	15410		10860
2000	16360		11357

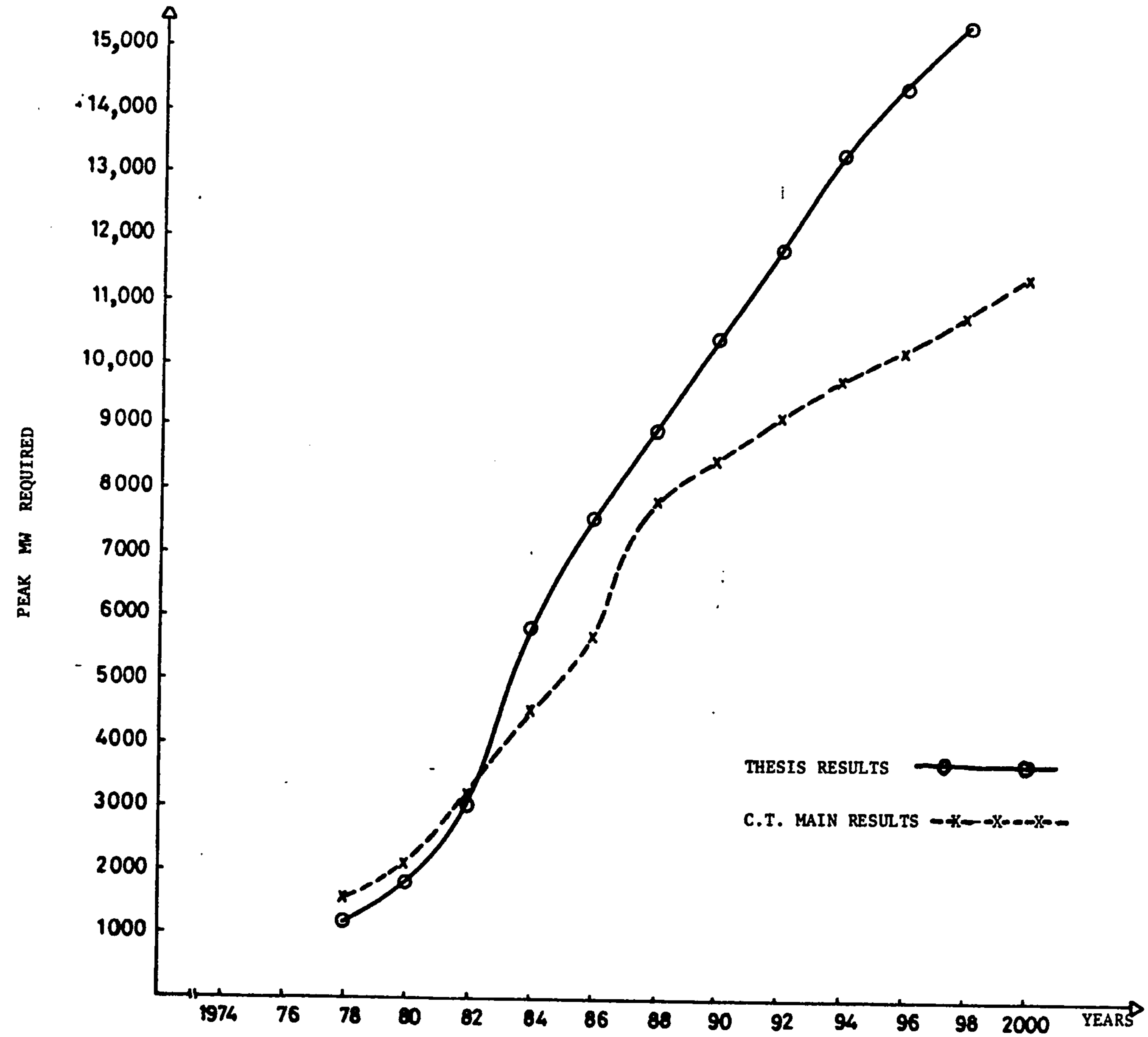


Figure 3.14. Comparison of the Peak MW between this study and C.T. Main Study for the Eastern Region.

|B| reached values for the peak load which are higher than the results obtained by |A| in the period (1978-1982).

2) Central Region:

Table 3.26 and Fig. 3.15 show the comparison between the peak MW in |A| and |B|. The results of |A|agree with those of |B|.

3) Western Region:

The biggest load center in the Western Region is Jeddah. However, the total peak load in this Region will be 8041 MW in the year 2000 according to |A| and 11970 MW according to |B|.

Table 3.27 and Fig. 3.16 show the comparison between the two studies for the Western Region |B| over estimated the peak load in this region from 1984 to the year 2000. The results for the period (1978-1982) are the same as in |A|.

4) Total Peak load in Saudi Arabia:

Table 3.28 and Fig. 3.17 show the comparison between the peak MW in |A| and |B|. The results show a reasonable agreement between the two studies.

TABLE 3.26. Comparison of the peak MW Between |A| and |B| for the Central Region.

YEAR	STUDY |A|	STUDY |B|
1978	395 |Actual|	342
1980	617	561
1982	956.5	911.5
1984	1363.5	1373
1986	1874	1846.5
1988	2405	2235
1990	2860	2588
1992	3273	3003
1994	3734	3423
1996	4252	3829
1998	4663	4283
2000	5104	4748

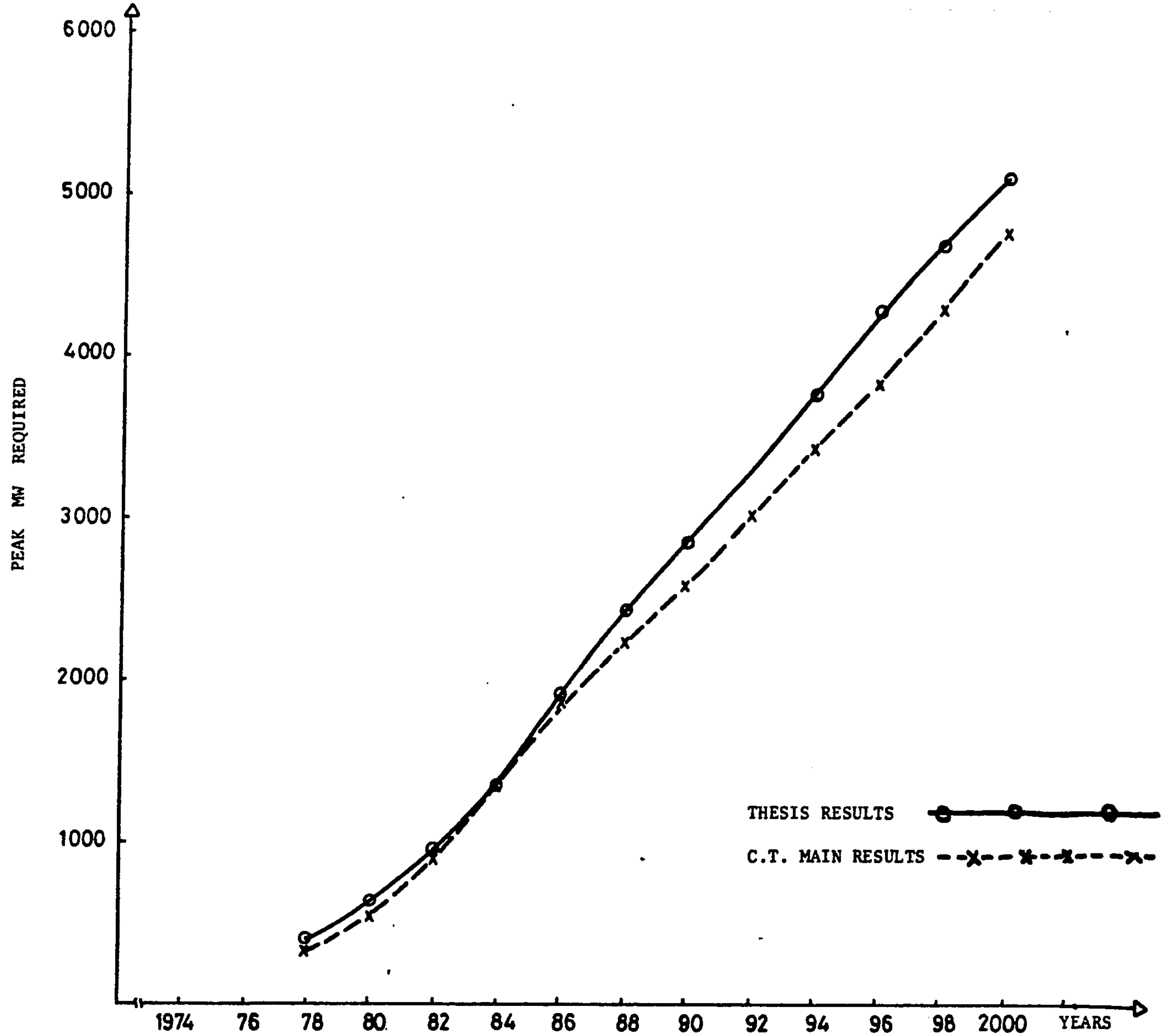


Figure 3.15. Comparison of the peak MW between this study and C.T. main study for the Central Region.

TABLE 3.27. Comparison of the Peak MW Between |A| and |B| for the Western Region.

YEAR	STUDY |A|	STUDY |B|
1978	638.5 |Actual|	634
1980	1011	1116
1982	1556	1921.5
1984	2232	3303
1986	3111	4794.5
1988	3968	6042
1990	4791	6835
1992	5530	7755
1994	6353	8715
1996	7199	9682
1998	7926	10768
2000	8641	11970

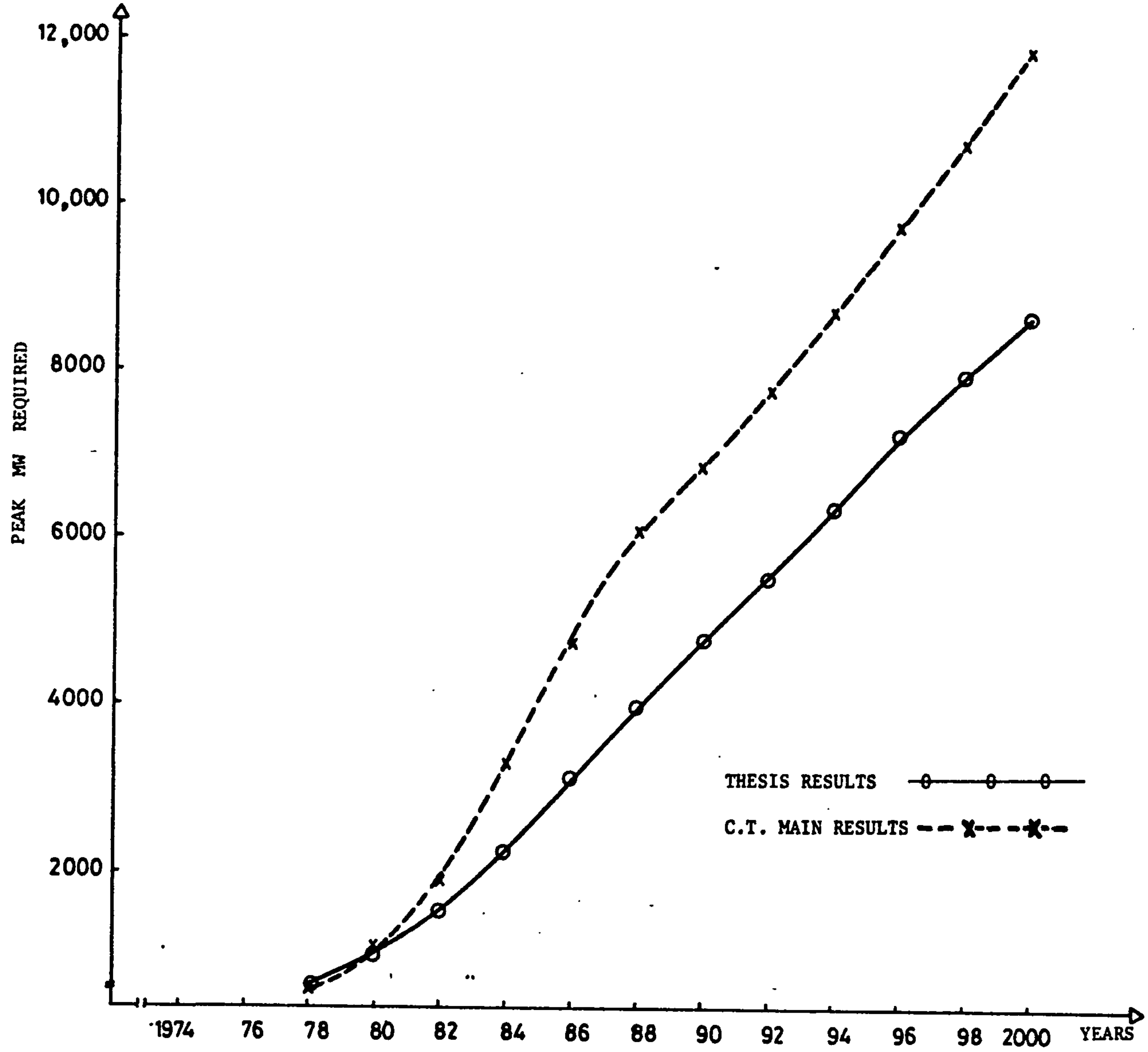


Figure 3.1c. Comparison of the peak MW between this study and C.T. main study for the Western Region.

TABLE 3.28. Comparison of the Peak MW Between |A| and |B| For the Kingdom of Saudi Arabia.

YEAR	STUDY |A|	STUDY |B|
1978	2223.5	2543
1980	3474	2846
1982	5522	6003
1984	9421.5	9210
1986	12512	12378
1988	15331	16164
1990	18069	17903
1992	20628	19903
1994	23387	21891
1996	25881	23792
1998	27999	25911
2000	30105	28075

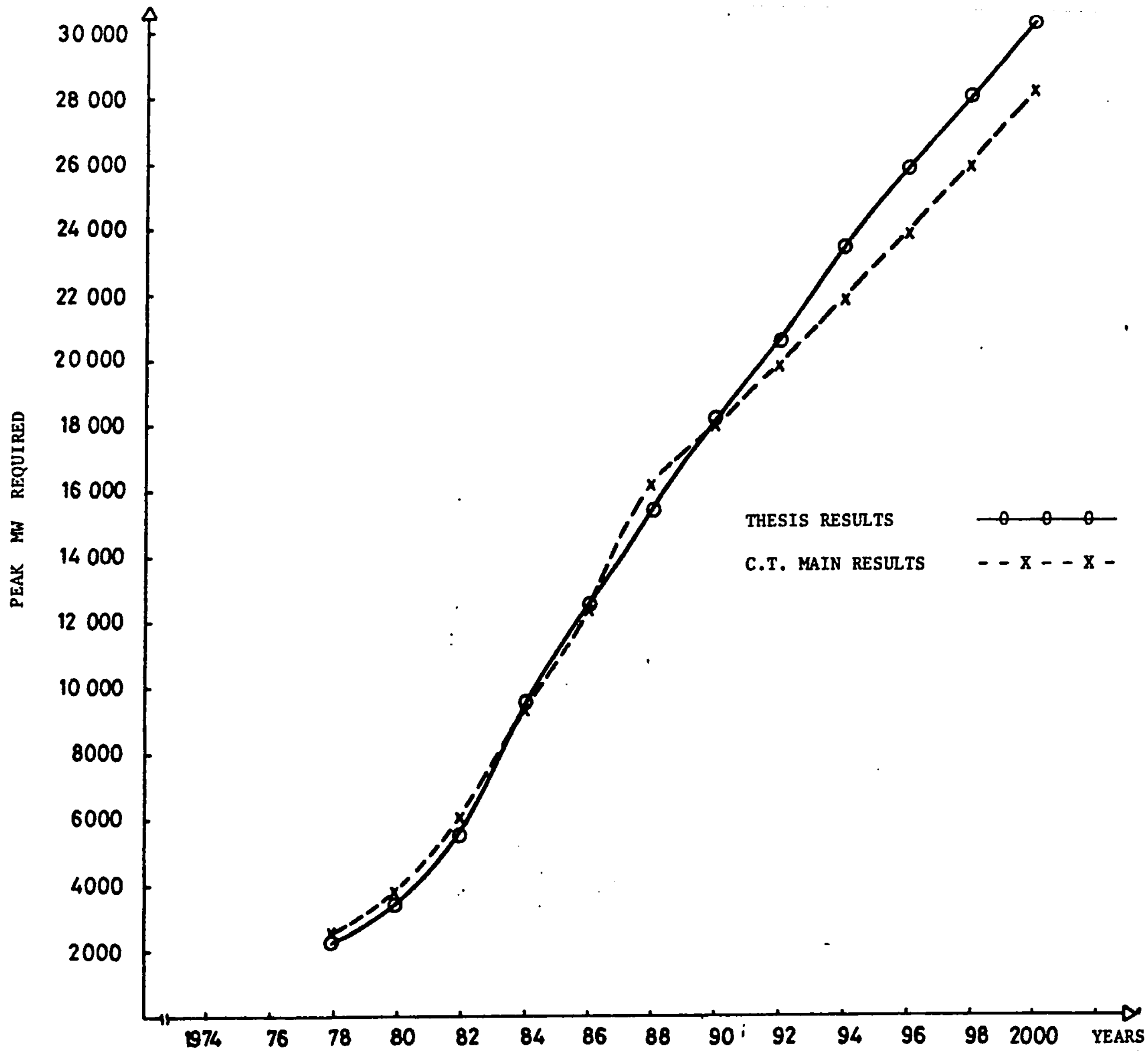


Figure 3.17. Comparison of the peak MW between this study and C.T. main study for the Kingdom of Saudi Arabia.

IV. MODES OF GENERATION

4.1. INTRODUCTION

The central power stations which supply an electrical system of which some may be considered for Saudi Arabia for the coming two decades are:

A - Hydro Electrical Generation.

B - Steam Electrical Generation.

C - Combustion Turbine (Gas Turbine).

D - Combined Cycle (Combustion and Steam Turbines).

E - Diesel Engine Units.

4.2. HYDRO ELECTRICAL GENERATION

The most economical and cheapest type of power generation is from hydraulic energy. Dams have been built in suitable sites to serve irrigation and other purposes in addition to the generation of electricity.

Irrigation governs the rate of water flow and not the electrical load demands. Hydro electrical generation plants are operated either base-load, peak-load, or combined base and peak load, depending on the water supply upstream. The potential energy locked in the water behind the dam, is converted into electrical energy when it flows through the hydro electrical generation units. Natural and main mode water falls are normal sites for dams with high heads and reliable water discharges. However, adequate hydro electrical generation sites are not available in Saudi Arabia.

The generation plan has to rely mostly on fossil fuels for the foreseeable future.

4.3. STEAM ELECTRICAL GENERATION

4.3.1 Description:

In a steam electrical generation system the fuel gives up its heat of combustion to a boiler which delivers steam at high temperature and pressure to the steam turbines. The steam uses its heat to drive the turbine. The turbine is in turn coupled directly or through a gearing system to an electrical generator. The need of water for cooling purposes makes its availability an important factor in choosing the plant site. Natural sources for large quantities of water in Saudi Arabia which come to the mind are the seas (The Gulf and The Red Sea).

4.3.2 Type of Fuels:

Steam electrical generators use a variety of fuels. They can be designed in such a way as to enable them to convert from one type of fuel to another at very little additional cost. Thus, steam electrical generation plants could burn either one of the following fuels:

(a) Fuel Oil.

(b) Crude Oil.

(c) Natural Gas.

(d) LPG (Liquified Petroleum Gas).

(e) Diesel.

4.3.3 Steam Electrical Plants:

The steam plants are available with nominal unit outputs of 100, 200, 400, 600, 800, 1000 and 1200 MW for installation in coastal areas. The installation of 2 units, 400 MW Steam electrical plants in Gazlan (Eastern Province, north of Ras Tanura)will be completed in mid-1980. The 400 MW steam unit represents a reasonable size for the early stages of development of the system in the eastern province while the 1200 MW unit is about the largest size considered to be practical for the latter stages of development with larger demands.

The steam electrical generation unit ratings are shown in Table 4.1. |26|

The net plant output includes deductions for plant auxiliary loads.

TABLE 4.1. Steam Electrical Generation Unit Rating.

NOMINAL OUTPUT (MW)	NET UNIT OUTPUT (MW)
100	92
200	184
400	368
600	552
800	736
1000	920
1200	1104

For inland steam generation requiring dry cooling towers, the net plant output is estimated to be equal to 0.85 of gross plant output. Table 4.2 shows the heat rating for different units of steam electrical generation. |26| Statistical data compiled in the United States by Edison Electric Institute have shown that, in the case of Steam units, the average availability of the unit is related to the unit size. Availability is governed by

(a) Forced Outages

(b) Scheduled Outages

(c) Maintenance Requirements.

Table 4.3 uses these data to represent the "availability" factors of large steam units. |18| Estimates of capital investment for steam plants burning fuel oil are shown in Table 4.4. |25|

The total annual costs for steam electrical generation in coastal areas, and a 400 MW steam unit located inland with dry cooling towers are plotted in Fig. 4.1 as a function of the annual hours of operation. |25|

TABLE 4.2. Steam Electrical Generation Heat Rating (Btu/KWh).

	PERCENT OF RATED LOAD		
Nominal Output (MW)	100%	80%	60%
100	10150	10170	10400
200	10050	10070	10300
400	9965	9985	10235
600	9900	9930	10200
800	9835	9875	10165
1000	9785	9845	10105
1200	9730	9775	10056

* 1 Btu/KWh = 0.25 Kilocalories/Kwh

TABLE 4.3. Availability of the Steam Electrical Generation Unit.

UNIT SIZE (NOMINALLY MW)	FORCED OUTAGES %	SCHEDULED OUTAGES %	MAINTENANCE %	TOTAL %	AVAILABILITY %
100	3.6	9.5	2.5	15.6	84.4
200	5.3	9.5	2.5	17.3	82.7
400	6	10.5	5	21.5	78.5
600	11	11.3	5.8	28.1	71.9
800	16	11.7	6.5	34.2	65.8
1,000	18.5	12	6.9	37.4	62.6
1,200	18.5	12	6.9	37.4	62.6

TABLE 4.4. Estimates of Capital Investment for Steam Plants.

NOMINAL OUTPUT (MW)	NET OUTPUT (MW)	COST ($ 1977/KW) NET IST UNIT	AVG. OF 2 UNITS
100	92	872	837
200	184	642	616
400	368	550	528
600	552	486	467
800	736	468	449
1,000	920	462	444
1,200	1,104	459	441

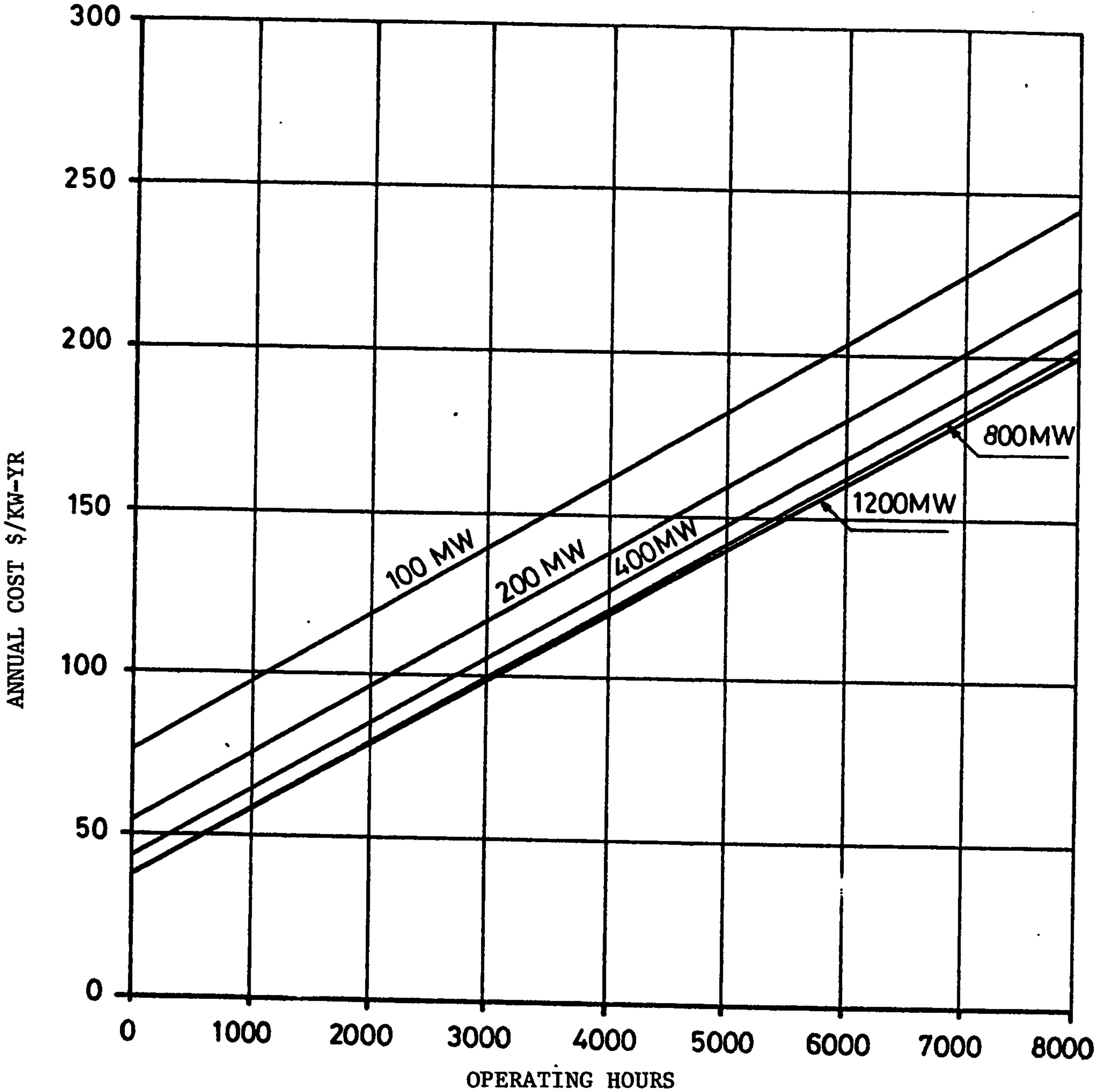


Figure 4.1. Steam Electric Plants total annual costs vs. operating hours .

4.4. COMBUSTION TURBINE - ELECTRICAL GENERATION

4.4.1 Description:

The essential components of a single-shaft "open cycle" gas turbine generator is shown in Fig. 4.2. Ten years ago the largest single shaft unit was rated at less than 15 MW, and the typical full load heat rate was about 60% - 70% higher than that of a comparable steam turbine. Today, units of up to 90 MW have been designed with heat rates only 25-30% higher than that of a steam turbine.

There are two basic types of combustion turbines on the market today:

(a) The industrial type which was originally designed as a hot-gas powered version of the steam turbine

(b) The jet type, which evolved as a combination of an aircraft type gas generator and a power turbine.

Of these two, the industrial type is historically more conservative and heavier with longer operating periods between overhauls, while the jet type is lighter and has a shorter start-up time. The jet type unit is available with up to eight jet engines driving one generator for a total output of over 200 MW, whereas the largest industrial

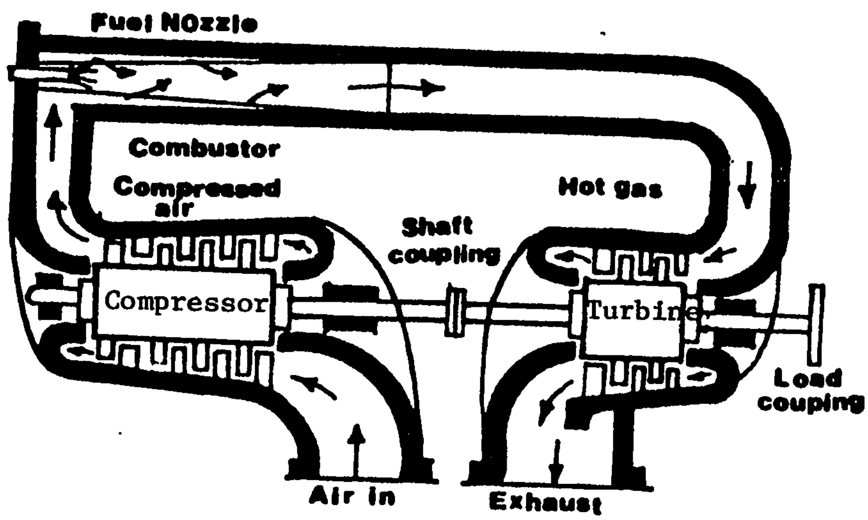


Figure 4.2. Combustion Turbine.

type unit currently produced is rated at about 90 MW. The industrial turbine is overhauled at site, while the jet engine is usually overhauled at a central workshop.

There are many variants in the makes of combustion turbine generators available on the market, particularly with respect to the need for elaborate foundations, eventual cooling water, ruggedness of construction, overall weight and maximum weight of any one component, extent of field erection required, ease of field inspection and maintenance, etc. These differences, which may make one type preferable to another for a specific site, should be carefully considered in the choice of a given project.

Many combustion turbines are capable of starting without any auxiliary electric power from an external source. This feature, coupled with the fast start, which can be achieved by remote control, marks this type of prime mover as eminently suitable for emergency standby purposes. Typical start-up time of an industrial combustion turbine is 15-20 minutes, and that of a jet type 4-5 minutes. In an emergency, these start-up times can be halved.

4.4.2 Type of Fuels:

The ideal fuel for combustion turbines, regardless of type, is natural gas. A ranking of fuels for combustion turbines, from the most desirable to the least, is:

(a) Natural Gas.

(b) Diesel.

(c) LPG

(d) Light Crude Oil.

(e) Heavier Crude Oil.

(f) Fuel Oil.

Most turbines can be built for dual fuel, i.e. to burn either gas or diesel and to automatically transfer from gas to oil under load. Heavy crudes oil cannot be fired in combustion turbines without proper fuel treatment to reduce contaminants to an acceptable level.

4.4.3 Combustion Turbine Plants:

A combustion turbine station consists of one or more simple cycle combustion turbines complete with all auxiliaries required for a self-contained generating station. Combustion turbine unit ratings were developed using typical manufacturer's data as shown in Table 4.5. |26|

Heat rates for combustion turbines were developed using typical manufacturer's data adjusted for temperature and altitude. Table 4.6 shows heat rates for coastal, inland and mountain applications. |26|

TABLE 4.5. Combustion Turbine Plant Unit Rating.

NOMINAL OUTPUT (MW)	NET UNIT OUTPUT (MW)			
	ISO* $15^{\circ}C(59^{\circ}F)$ SEA LEVEL	COASTAL $38^{\circ}C(100^{\circ}F)$ SEA LEVEL	INLAND $49^{\circ}C(120^{\circ}F)$ 610m(2,000 FT)	MOUNTAINS $38^{\circ}C(100^{\circ}F)$ 2,100m(7,000 FT)
20	19.7	17	14	13
30	30.0	26	22	20
60	60.0	50	43	40
90	86.9	73	63	58

* ISO = International Organization for Standardization.

TABLE 4.6. Combustion Turbine Heat Rates (Btu/Kwh).

NOMINAL OUTPUT (MW)	PERCENT LOAD				
	100	80	60	40	20
	Coastal - Sea Level, 38°C (100°F)				
20	13,696	14,790	17,523	20,247	22,932
30	13,512	14,349	15,960	19,526	20,856
60	12,767	13,585	14,973	16,914	18,781
90	12,220	12.627	14,620	16,701	18,220
	Inland - 610 m (2,000 ft.), 49°C(120°F)				
20	14,155	15,285	18,110	20,925	23,700
30	13,965	14,830	16,495	20,180	21,555
60	13,195	14,040	15,475	17,480	19,410
90	12,630	13,050	15,110	17,260	18,830
	Mountains - 2100 m (7,000 ft.), 38°C (100°F)				
20	13,696	14,790	17,523	20,247	22,932
30	13,512	14,349	15,960	19,526	20,856
60	12,767	13,858	14,973	16,914	18,781
90	12,220	12,627	14,620	16,701	18,220

4.4.4 Combustion Turbine Capital Investment:

The combustion turbines and accessories were priced for the Middle East operating conditions of high temperatures and wind-blown sand. Table 4.7 shows the estimated cost of combustion turbine (capital investment), and Fig. 4.3 plots the annual cost (1977 $/KW-YR) against the annual operating hours. |25|

There are some important differences between the steam turbine and the combustion turbine. The steam boiler can burn fuel oil but the combustion turbine cannot burn fuel oil efficiently. Furthermore, its maintenance cost is much higher than that of a steam power plant when burning fuel oil or crude oil. Steam turbines are not affected by atmospheric conditions, while with a combustion turbine both higher elevations and higher ambient temperature reduce output and efficiency. Most combustion turbines do not require water for cooling except in small quantities.

Combustion turbines are being installed by many utilities as peaking unit because of their fast start up and their relatively low investment cost.

TABLE 4.7. Combustion Turbine Capital Investment.

NOMINAL OUTPUT (MW)	NET OUTPUT (MW)	COST/KW (1977 $ NET)
Coastal Areas		
20	17	337
30	26	322
60	50	288
90	73	270
Inland Areas		
20	14	409
30	22	382
60	43	335
90	63	314
Mountain Areas		
20	13	441
30	20	418
60	40	360
90	58	340

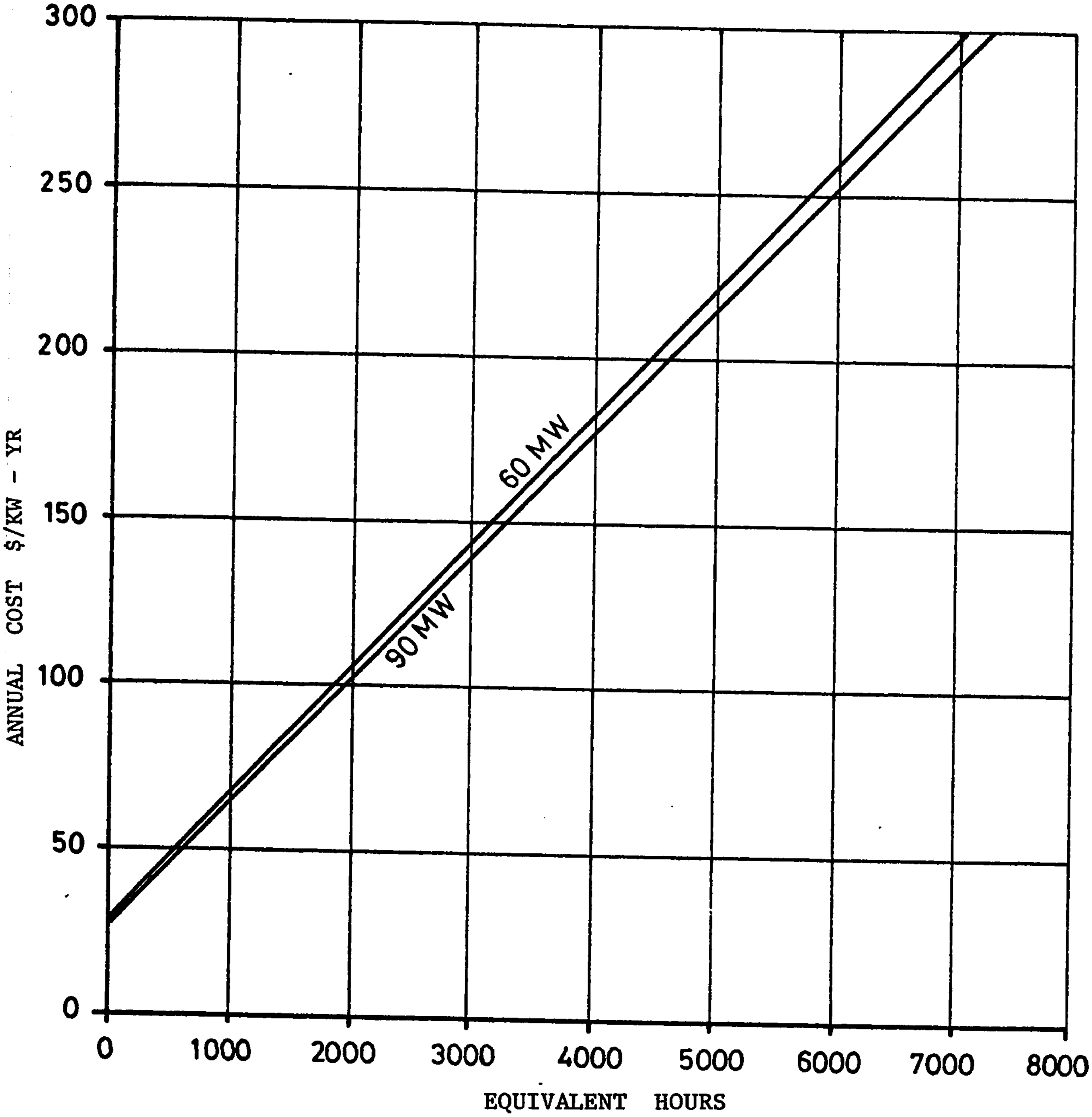


Figure 4.3. Combustion Turbines (distillate fuel)

Total Annual Costs vs. Operating Hours.

4.5. COMBINED CYCLE (COMBUSTION AND STEAM TURBINES).

4.5.1 Description:

This type of plant consists of a combustion turbine exhausting into a waste heat boiler for steam generation and a steam turbine with the usual auxiliaries to produce electricity.

The advantages of combining combustion and steam turbines have been recognized for many years. The basic advantage and the theoretical reason for such gains become apparent when the two power cycles are analyzed. In the combustion turbine simple cycle efficiency is adversely affected by the high heat rejection temperature of the discharge gas. The steam cycle on the other hand has a rather low heat sink temperature for the heat rejected through the condenser. When the combustion turbine is combined with the steam turbine, the sink temperatures are lowered to approach those of the steam cycle by the transfer of heat from the higher combustion turbine cycle temperature. Therefore, the fundamental advantage of this combination is a lower heat rate. The combined effect exceeds the efficiency of either cycle alone and compares favorably with conventional steam units of much larger capacity. An operational benefit of the combined cycle plant is that it can provide full power to the system in less than one hour. Combined cycle units, as far as reliability and availability are concerned, are preferable to steam electric stations.

4.5.2 Type of Fuels:

Combined cycle units can burn a variety of fuels and can be designed to convert from one type of fuel to another at very little additional cost. The combined cycle units could burn either one of the following:

(a) Fuel Oil.

(b) Natural Gas.

(c) Diesel.

(d) LPG (Liquified Petroleum Gas).

(e) Crude Oil.

4.5.3 Combined Cycle Plants:

Combined cycle plants with nominal unit outputs of 200, 400 and 800 MW for installation either in coastal or inland areas are considered as representative unit sizes. The relationship of net plant output to nominal plant output assumed for combined cycle plants is reported in Table 4.8. |26|

Heat rates for combined cycle units were developed using typical manufacturer's data adjusted for temperature and location. Table 4.9 shows heat rates for coastal

TABLE 4.8. Combined Cycle Plant Unit Ratings.

NOMINAL OUTPUT (MW)	NET PLANT OUTPUT (MW)		
	ISO*	SEA LEVEL 38°C(100°F)	610 m (2,000 FT.) 49°C (120°F)
200	194	175	158
400	388	360	316
800	776	720	632

* ISO = International Organization for Standardization.

TABLE 4.9. Combined Cycle Plant Heat Rates (Btu/Kwh).

NOMINAL OUTPUT (MW)	PERCENT LOAD 100	80	60	40	20
	Coastal-Sea Level (Once-Through Cooling).				
200	8,690	8,985	9,105	9,435	10,200
400	8,605	8,900	9,045	9,345	10,200
800	8,595	8,885	9,035	9,330	10,185
	Inland-610 m (2000 ft.) Dry Towers.				
200	9,455	9,805	10,025	10,475	10,930
400	9,360	9,715	9,930	10,375	11,755
800	9,350	9,700	9,915	10,360	11,735

and inland applications. |26|

Heat rates in combined cycle plants are not significantly affected by ambient temperature conditions as those of simple cycle combustion turbines.

The estimates of capital investment have been developed for three sizes of plants, 200, 400 and 800 MW. Table 4.10 shows the estimated cost of combined cycle plant (capital investment). |25|

The total annual costs are plotted in Fig. 4.4 as a function of operating hours. |25|. In some cases, combustion turbines in a plant are arranged to enable future conversion to combined cycle operation of the combustion turbines.

4.6. DIESEL ENGINE UNITS

Diesel engine driven generating units are being recommended for supply to isolated and developing loads in the range of 100 KW up to 20 MW.

These units are constructed in a wide variety of sizes and speeds by a number of manufacturers. The operating speeds available range from 120 rpm for 20-25 MW units to 1800 rpm for machines rating less than 1 MW. In general, smaller high-speed units cost less per KW than larger

TABLE 4.10. Combined Cycle Plant Capital Investment.

NOMINAL OUTPUT (MW)	NET OUTPUT (MW)	COST (1977 $/KW)	
		IST UNIT	AVG. 2 UNITS
Coastal Areas			
200	175	430	413
400	360	390	374
800	720	372	357
Inland Areas - 610 m (2000 ft.) Dry Towers			
200	158	502	482
400	316	464	445
800	632	438	420

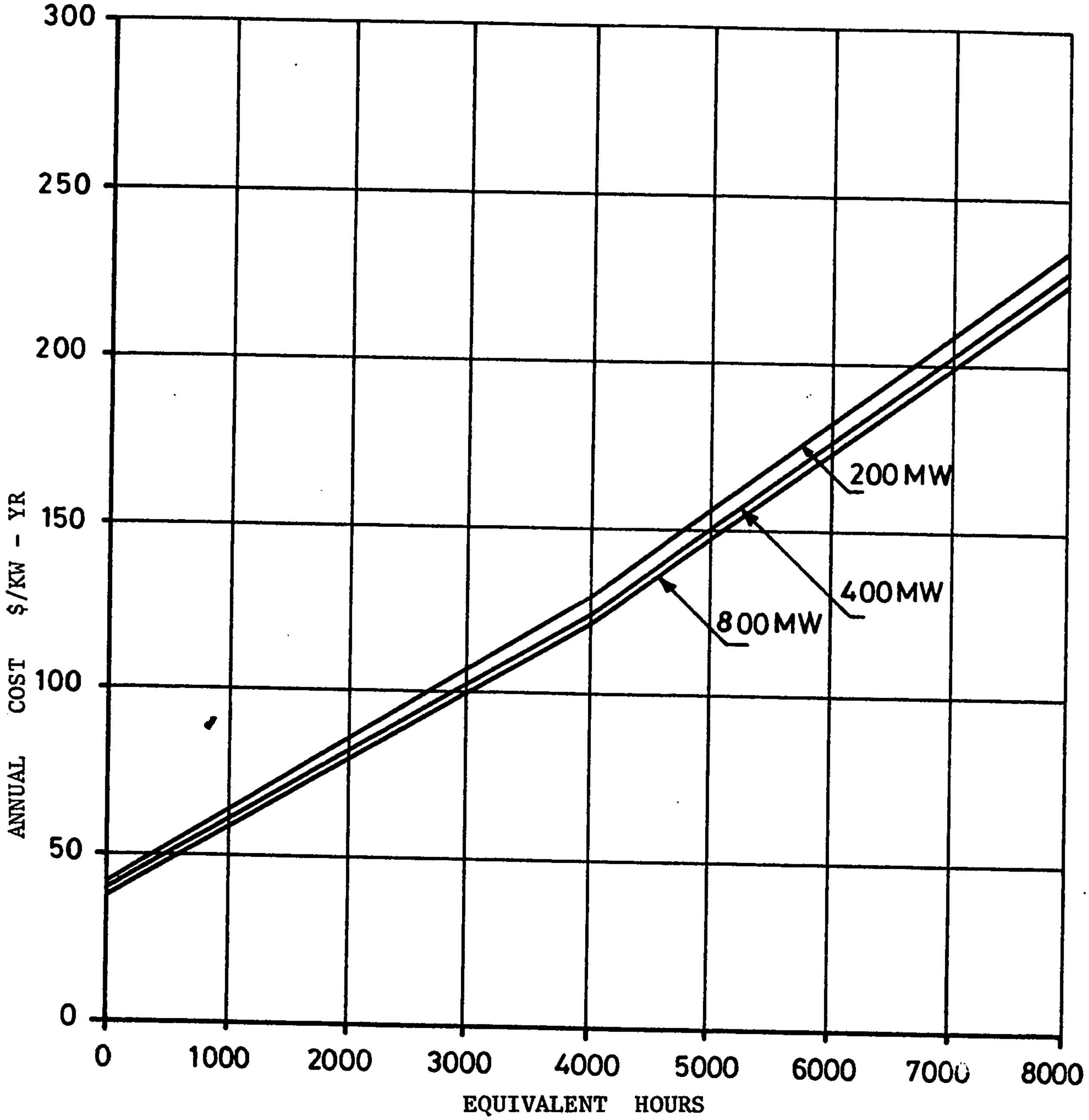


Figure 4.4. Combined cycle plant (residual fuel)
Total Annual Costs vs. Operating Hours.

lower-speed ones. For units operating in any particular speed range, small units cost more per KW than the large size units in that speed range.

The low speed units are characterized by higher capital costs, lower heat rates, long life expectancy, lower maintenance, and the ability to burn low-cost, treated crude oil. The high speed units are noted for the opposite characteristics, and their requirement of burning higher cost distillate fuels. Table 4.11 summarizes the typical values which may be expected for installation in Saudi Arabia. |25|

For loads in the 10-20 MW range, small combustion turbines may compete economically with diesel engine units. The installed cost of the small combustion turbines is estimated to be some 40% less than that of the diesel engines. However, it is offset by higher, 15,000 Btu/KW, heat rate of the combustion turbine, and the ability of the diesel engines to burn lower-cost treated crude-oil as opposed to distillate-fuel required for the combustion turbine.

The choice of the sizes, speeds and types of fuel for specific loads of a diesel unit will be determined by many factors including the size of the load, the number of units needed for service reliability, the load factor, location

TABLE 4.11. Typical Values of the Diesel Engine Units.

RANGE OF NOMINAL SIZE	TYPICAL SPEEDS AVAILABLE RPM	RANGE OF COSTS PER KW (1977$)	TYPICAL HEAT RATES BTU/KWH	TYPE OF FUEL	
				DIESEL	TREATED CRUDE OIL
100 KW to 1000 KW	1800, 1200 and 900	900 to 300	13000 to 12000	X X	
1 MW TO 10 MW	720, 514 and 450	900 to 600	12000 to 10000	X X	X
10 MW TO 20 MW	450, 150 and 120	1000 to 800	10000 to 8800	X X	X X

and local conditions, availability of fuel, sizes available from manufacturers, and costs.

4.7. COMPARISON OF DIFFERENT TYPES OF GENERATORS

In the previous sections, comparative costs of generation were developed for the following types and sizes of generators.

Combustion Turbines	60 - 90 MW
Steam Turbines	200 - 1000 MW
Combined Cycle Turbines	200 - 800 MW

Figure 4.5 shows the net annual heat rating for different types of electrical generators. |26| The higher rating is for combustion gas turbines and the lower rating is for combined cycle.

Figure 4.6 shows the comparative capital investments in 1977 $/KW for the various unit sizes and types of electrical generation. |25| The higher investment cost is for steam turbines in inland areas due to the installation of dry towers. On the other hand, steam turbines in coastal areas have reasonably low costs in sizes between 800 - 1000 MW. Figure 4.7 shows the relative economy of the three types of fossil fired generators, the steam turbine has the lowest operation and maintenance costs. |25|

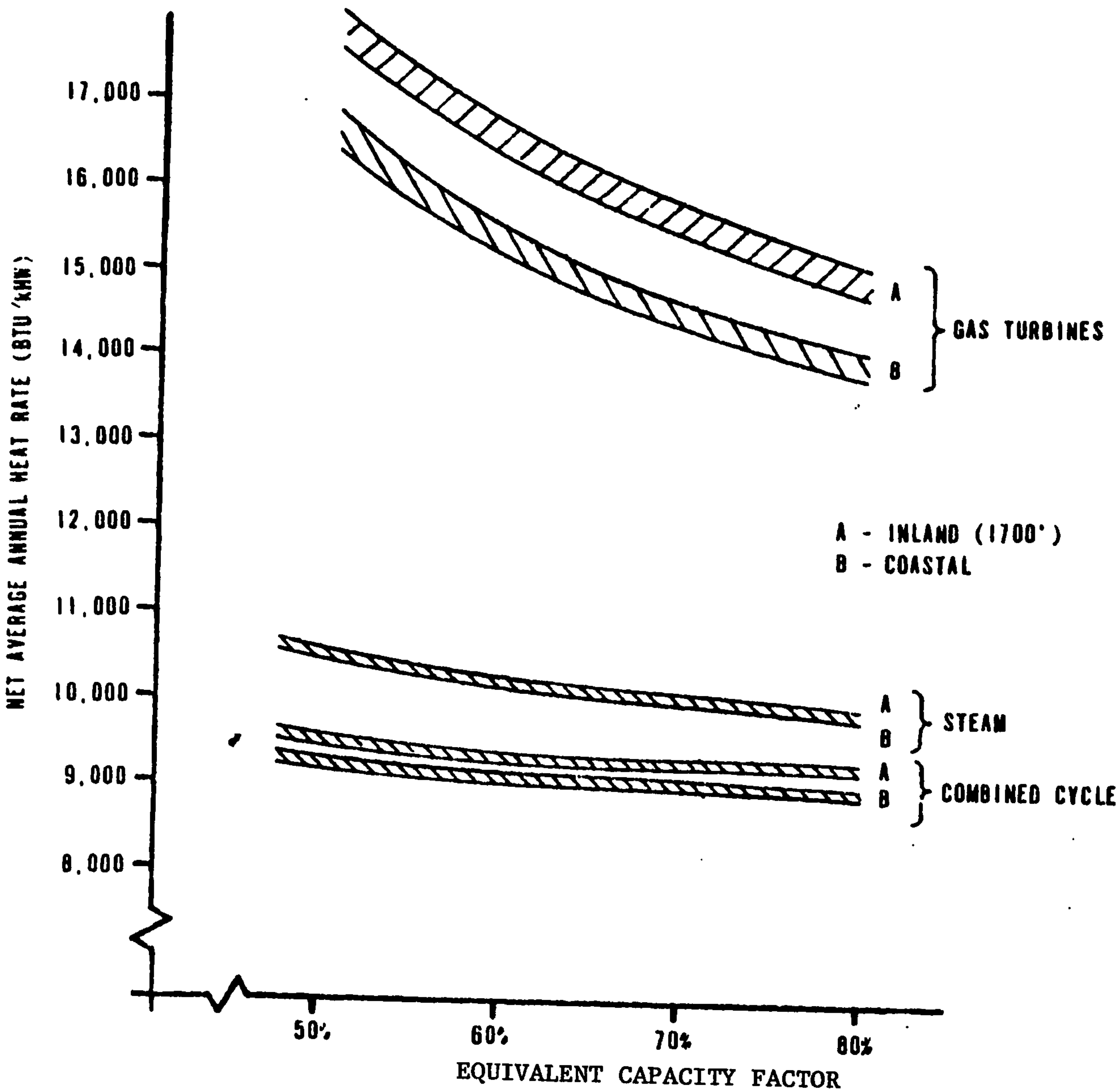


Figure 4.5. Typical Heat Rates for a Range of unit sizes.

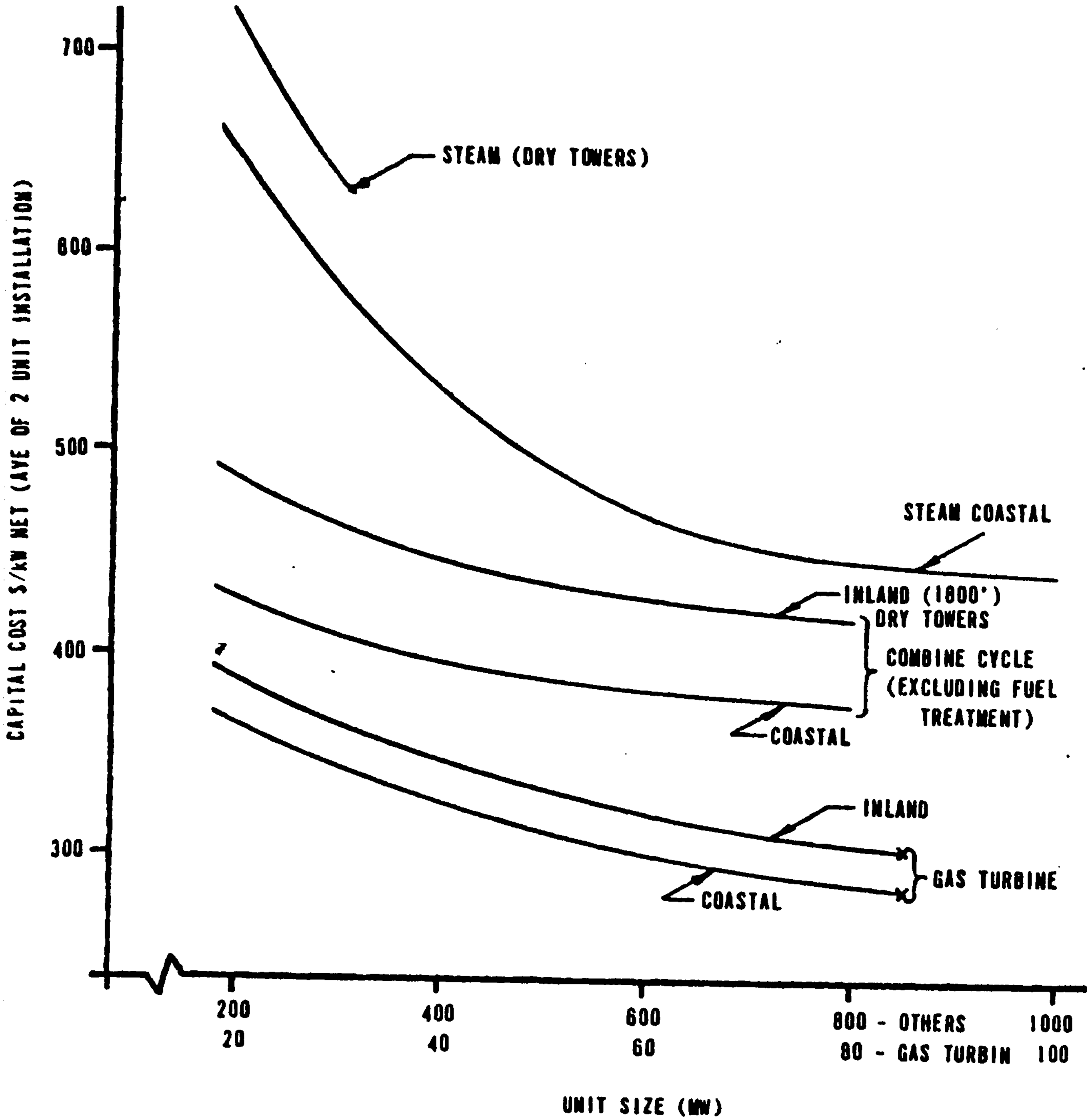


Figure 4.6. Capital investment in 1977 $/KW for various unit sizes.

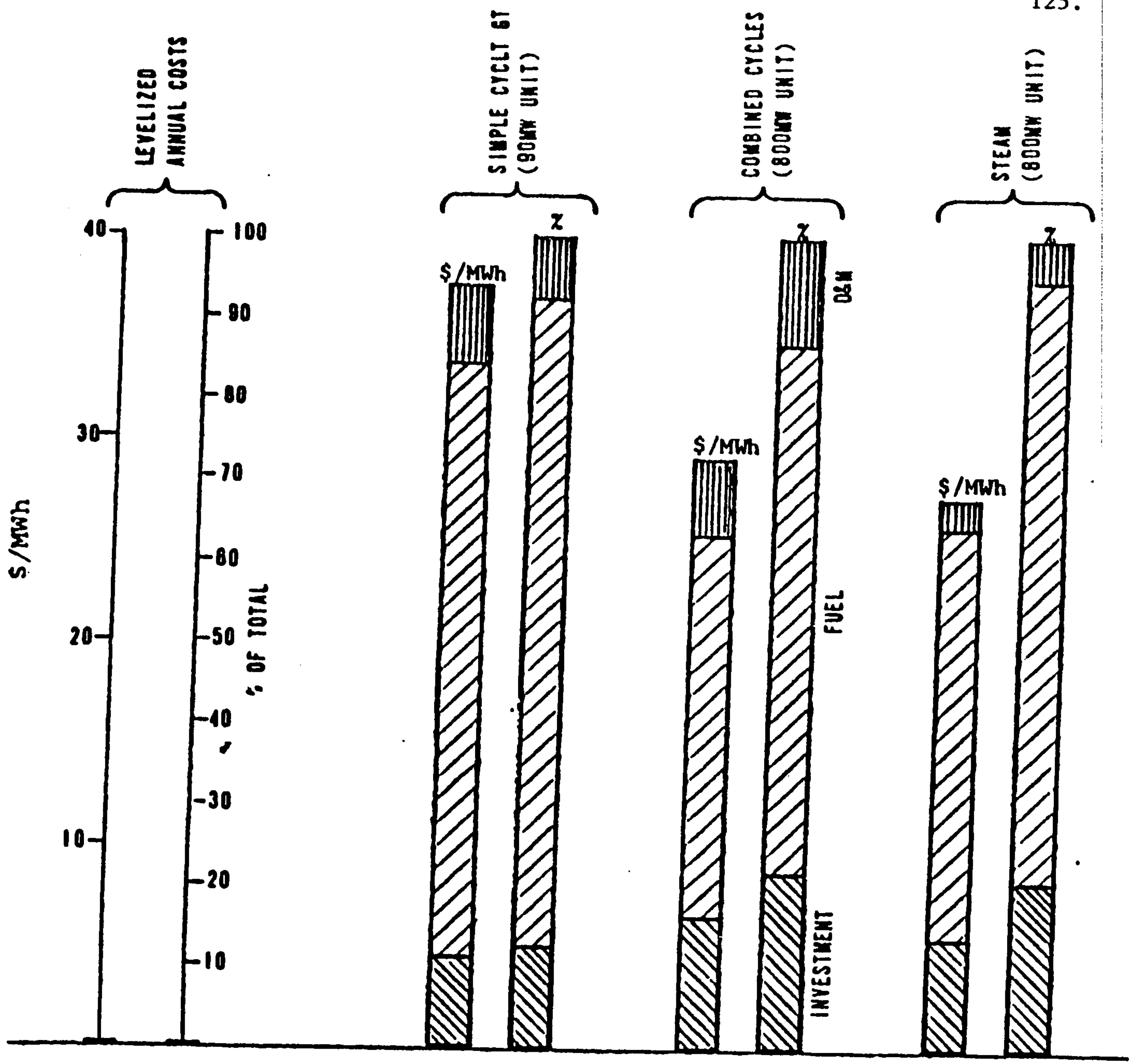


Figure 4.7. Relative total annual costs.

* assumes 6000 hrs. equivalent full load operation.

It would appear that, in the comparison of different types of fossil fired generators, the following key conclusions should be drawn:

A - Base load generation should be provided by steam plants, in the coastal areas on the Eastern and Western Regions.

B - It would appear advisable to install combustion turbines in the Central Region, with a view to possible future conversion to combined cycle operation for peak load in the coastal areas.

The advisable rating for the combustion turbines is in the range of 60 to 90 MW.

C - In the areas where the load is in the range of 10 to 50 MW, the diesel engine appears to be the best alternative, if it is not economically possible to interconnect the system to the major central generation network.

D - In isolated and remote areas, small diesel engines will be the best solution for minimum cost.

V. OTHER ALTERNATIVES OF GENERATION ELECTRICITY

5.1. ATOMIC ENERGY TO GENERATE ELECTRICITY

Comparison of nuclear power plants with fossil-fired power plants indicates a distinct cost advantage for nuclear generation. The cost of electricity from a large nuclear power plant is twenty percent cheaper than an equivalent fossil-fired steam plant |25|. This is shown in Fig. 5.1 and Fig. 5.2 which compares costs of electric energy from both nuclear and fossil-fired units and also shows the relative weights of the capital investment, fuel, and operation maintenance components of the cost of electricity. |25| Here, it can be seen that there is greater risk in selecting a nuclear fuel alternative due to its higher initial investment.

The development of a nuclear alternative depends on many related issues which are important in the development of the nuclear industry within a given country.

Saudi Arabia is now producing 8.5 million barrels of oil daily. Along with oil, vast amounts of gas are also extracted and most of it flared. The availability of these two sources of energy and the proved capability of using them safely makes them most suitable to generate electricity for the next fifteen to twenty years.

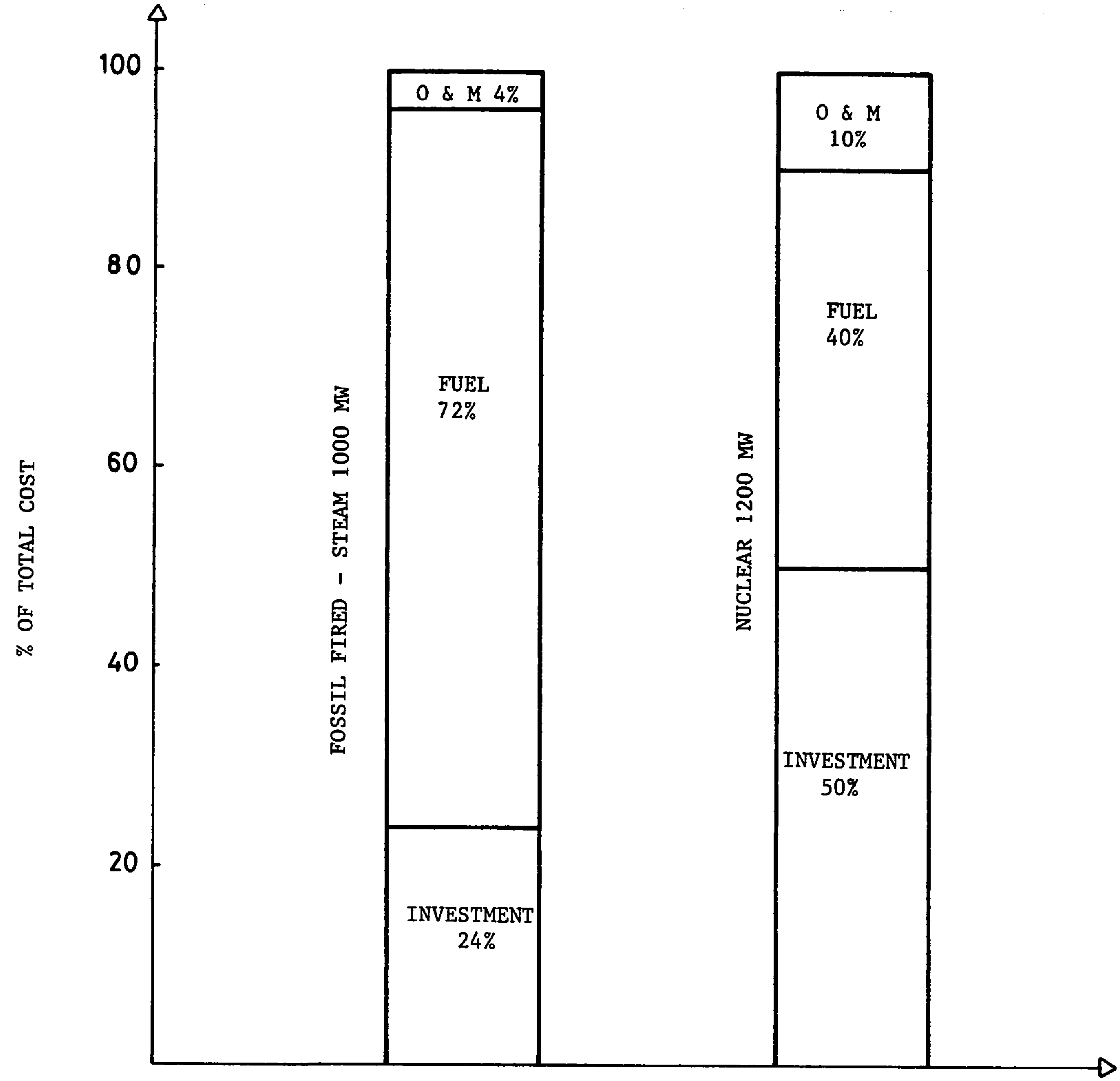


Figure 5.1. Comparison between Steam Generation and Nuclear Generation.

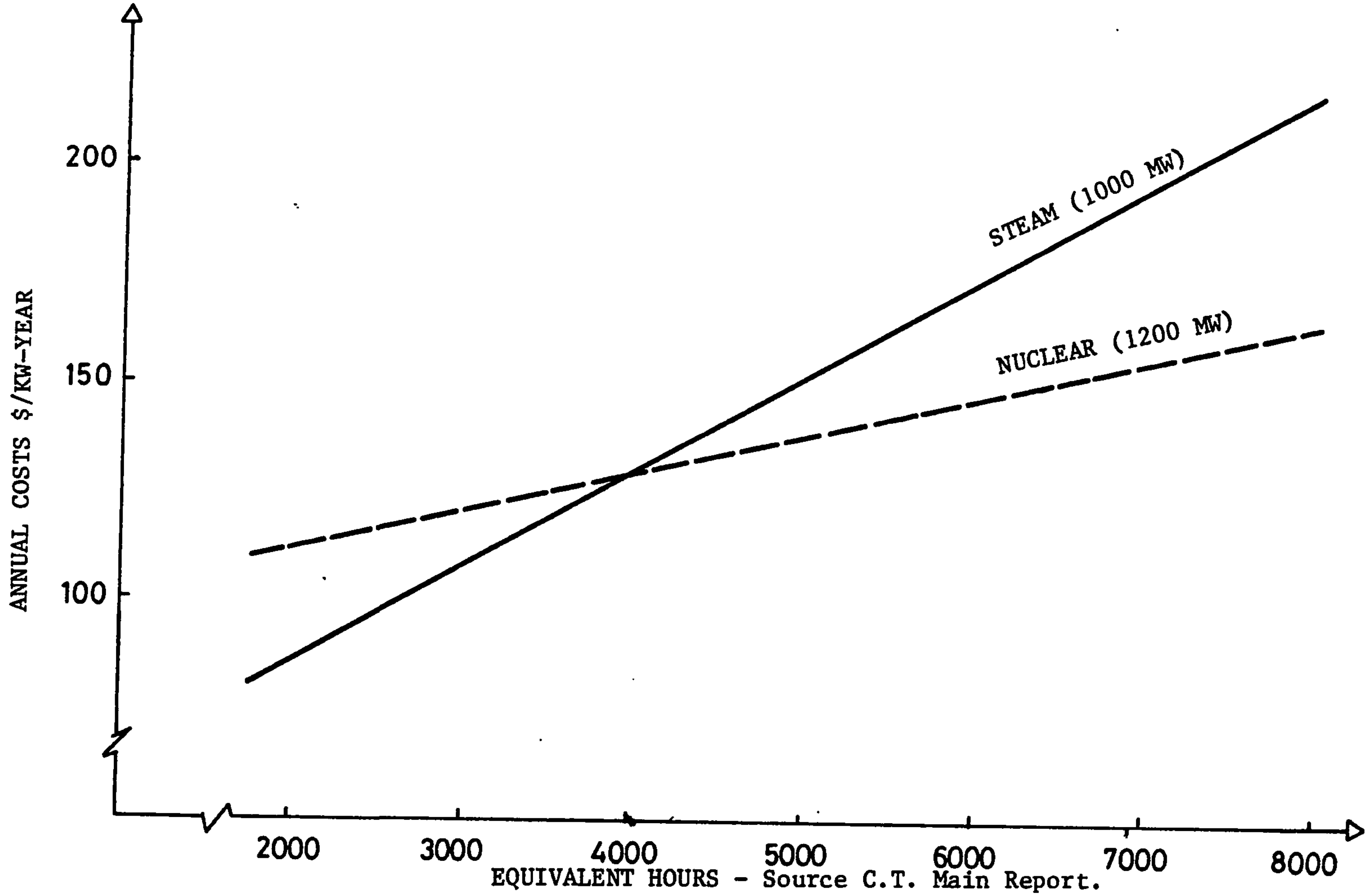


Figure 5.2. Comparison between Steam Generation and Nuclear Generation Annual Cost.

The following six points should be considered before Saudi Arabia attempts to utilize Atomic Energy to generate power:

1. Is raw uranium available in the Kingdom? The answer to this question is unknown. Unless that material is available, it will become necessary to import it from abroad. Foreign governments restrict exporting uranium by attaching unacceptable conditions. Availability of uranium in the Kingdom is the first condition for its use.

2. Are safety standards to handle atomic materials adequate?

The highest safety standard must be considered because an atomic leak could be disastrous. The U.S. Government who has been enforcing highest safety standards found out the hard way that their best was not good enough. Here in the Kingdom our safety standards on ordinary plants are inadequate.

3. Is protection of atomic plants from foreign sabotage adequate?

If safety standards are inadequate, the answer to this question would be the same as above.

4. Is Technical Know-How available?

We are now depending on foreign labor to operate ordinary plants. Depending on imported labor to operate such a highly sophisticated plants is unacceptable.

5. Is it economical to establish atomic plants in the Kingdom?

As long as we continue to burn-up excess gas, it is quite obvious that it is not economical to use any other source of energy to generate power.

6. Are funds available to install and operate atomic plants?

The answer to this question is affirmative.

A close examination of the above six points will point out that the only positive item is the availability of funds. If we must import raw materials, import the technology and the skilled labor to operate and maintain atomic plants, then we will be completely dependant on foreign governments. On the other hand, the safety hazard is great.

Since oil is plentiful, gas is flared, plants to generate power with oil and gas are available, and since the skilled labor to operate them safely is available in the Kingdom, it is not advisable to contemplate atomic electricity during the next fifteen to twenty years.

It is uneconomical, and unsafe for the entire Kingdom of Saudi Arabia to use atomic energy to generate power at present.

5.2. DUAL PURPOSE WATER DESALINATION AND ELECTRICAL GENERATION

5.2.1 Introduction:

The evaluation of the growth of water demands for the future economical and social development in Saudi Arabia, and the available ground water resources show that Saudi Arabia will need large new sources of fresh water to supplement its natural water resources. For the immediate future, the multi-stage flash desalination of sea water is the principal proven technology for the production of large amounts of fresh water. However, in the future, conservation and recycling practices may become widely used, and piping water from major rivers such as the Nile, or the towing of icebergs from the Antartic, may become practical.

The process of multi-stage flash distillation basically consists of a number of shell and tube heat exchangers installed in series. Steam is supplied to heat the sea water which is pressurized to prevent vaporization through the tubes in the heater. The hot sea water then enters a flash chamber where pressure and temperature are at lower level. A portion of the incoming water flashes into vapor that is quickly condensed by impinging on the condenser tubes which carry the sea water to the heater. The remaining portion of the hot sea water passes to the next flash chambers where the same cycle repeats itself.

Energy for the desalination plant may be supplied from any heat source (e.g.,steam generator). However, power plants when supplemented with desalination plants result in considerably improved economics for both power generation and water desalination.

In dual purpose plants, the heat for desalination cycle is supplied by low and/or intermediate pressure steam extracted from a steam turbine generator. This results in generation of electricity at high efficiencies, as direct condenser losses are reduced by the quantity of steam extracted in the evaporation process.

5.2.2 Types of Dual-Purpose Plants:

The dual purpose plant is more complex since the turbine generator must follow electric network loads, while the distillation process must continue through load variation and at times when the turbine generator is out of service. Two types of dual purpose desalination plants exist, namely back-pressure and extraction types. In the back-pressure type, the steam is supplied to the brine water heaters after having been expanded in the turbines. In the extraction plant, steam is extracted at conditions suitable for the brine heaters, while the balance of steam at low pressure is further maintained in the turbines.

The back pressure type is applicable to plants having a low power-to-water ratio. Such plants require relatively low investments, and have a good efficiency when operated at the rated capacity. However, operation at significantly less than rated capacity leads to high operating costs.

The extraction type, on the other hand, permits good operation at partial loads, and the power-to-water ratio can be varied from low values to values higher than with the back-pressure cycle. However, the sophisticated design of the turbine in the extraction cycle needs additional investment cost.

In the design of a dual purpose power and water plant, three major factors are taken into account, which are

a) The amount of water to be produced.

b) The amount of electric energy to be generated.

c) The mode of operation (i.e. base or peak loading for water, power, or both).

5.2.3 Saline Water Conversion Corp. (SWCC):

The primary purpose of the Saline Water Conversion Corp. is to develop potable water for use in the Kingdom. As a result of the design of most of these facilities, a considerable amount of electrical generation will become available to the electric utility companies.

There was only one desalination/generation plant in Saudi Arabia by the end of 1978. It is located in Jeddah (Western Province) and it is producing 150 MW of electricity and 15 MG of water per day. Tables 5.1 and 5.2 show the projected plans for dual purpose plants in different regions in Saudi Arabia. |40| Figure 5.3 shows the location of the existing and proposed plants of dual purpose plants until 1986. It is estimated that the rate of increase of power generation from dual purpose plants during the period (1987-2000) will be 200 MW/year. In the year 2000, the total power generation from dual purpose plants will reach 8000 MW.

TABLE 5.1. Desalination and Power Plant Operating or Planned for Construction in the Western Region of Saudi Arabia.

NAME OF DESALINATION PLANT	PHASE	CAPACITY WATER THOUSAND GALLONS/DAY	POWER MW	TYPE OF FUEL	ESTIMATED DATE OF OPERATION
Jeddah	1	5,000	50	Crude Oil	Operating since 1970.
	2	10,000	100	"	Since 1978
	3	20,000	200	"	1981
	4	50,000	500	"	1983
Yanbu &	1	25,000	250	"	1982
Medina	2	40,000	400	"	Under study (1986)
Rabigh	1	240	-	"	1980
Ummlujj	1	120	-	"	Since 1975
	2	1,000	10	"	1981
Al-Wajh	1	60	-	"	Since 1969
	2	120	-	"	1980
	3	1,200	10	"	1983
Duba	1	60	-	"	Since 1969
	2	120	-	"	1979
	3	1,000	10	"	1981
Haql	1	120	-	"	1979
	2	1,500	15	"	1980
Al-Leeth	1	120	-	"	1979
Al-Qunfudah	1	1,000	10	"	Under study (1985)
Frasan	1	132	-	"	1979
Mecca	1	50,000	500	"	Under study (1986)
TOTAL WESTERN REGION UP TO 1986		206,792	2,055		1986

TABLE 5.2. Desalination and Power Plant Operating or Planned for Construction in the Eastern Region of Saudi Arabia.

NAME OF DESALINATION PLANT	PHASE	CAPACITY WATER THOUSAND GALLONS/ DAY	CAPACITY POWER MW	TYPE OF FUEL	ESTIMATED DATE OF OPERATION
Al-Khobar	1	7,500	-	Natural Gas	Since 1974
	2	50,000	500	"	1982
	3	40,000	400	"	Under study (1986)
Al-Jubail	1	30,000	300	"	1981
	2	175,000	1,750	"	1983
Al-Khafji	1	120	-	"	Since 1974
	2	5,000	50	"	1982
	3	25,000	250	"	Under study (1986)
TOTAL EASTERN REGION UPTO 1986		332,620	3,250		1986
TOTAL KINGDOM OF SAUDI ARABIA		539,412	5,305		1986

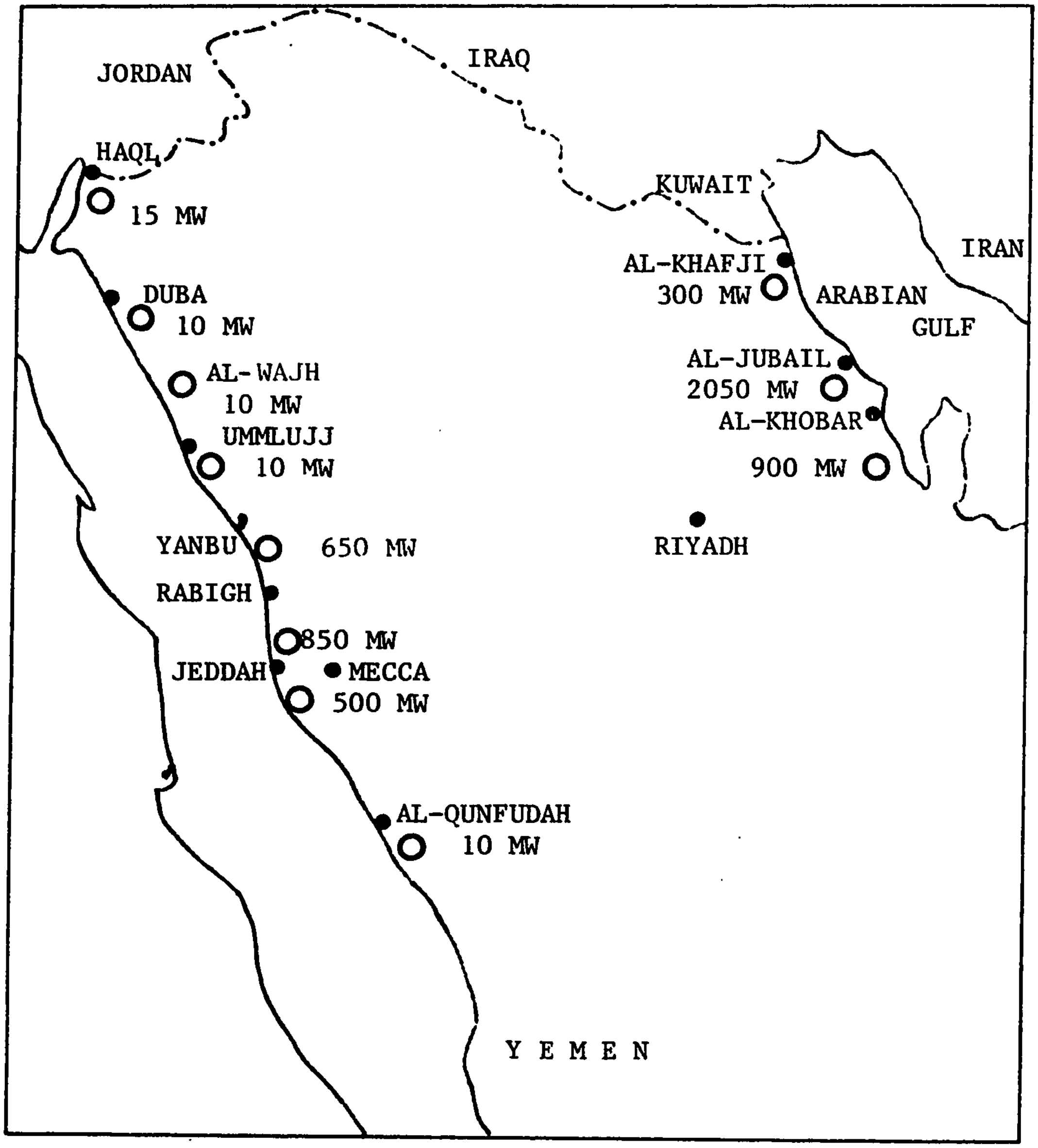


Figure 5.3. Saline Water Conversion Corp. (SWCC) map existing and proposed plants (1986).

5.3. ELECTRICAL SOLAR ENERGY TO GENERATE ELECTRICITY

Large scale conversion of Solar energy into electricity can be made by two different systems:

(a) Photovoltaic System.

(b) Solar Thermal System.

5.3.1 Photovoltaic System:

Arrays of photovoltaic cells, coupled with concentrating collectors, are seen as a potentially effective method of generating electricity directly. The estimated capital cost per KW for a photovoltaic system is \$ 1600, effective in 1985. The present cost is around \$ 18,000 per KW |24|.

5.3.2 Solar Thermal System:

One high-temperature thermal system proposed for electrical power generation is the power tower. A field of heliostats focuses solar radiation on a control collector atop a tower. The boiler is also positioned at the top of the tower.

The size of such a system could range from a few magawatts upto 100 MW. The cost is expected to be \$ 1200/KW in 1980's. At present the cost is around \$ 12,000 per KW. |24| There are some pilot projects under way but the system is not yet commercially available.

5.3.3 Conclusion:

It is recommended to undertake a more detailed study of costs of those solar energy systems which may appear potentially to be cost competitive with alternative electric systems.

VI. RECOMMENDED PROCEDURES FOR A LOAD FORECASTING METHODOLOGY FOR THE KINGDOM OF SAUDI ARABIA

6.1. INTRODUCTION

Electrical utilities are relying more and more on forecasts to support future financial requirements and justify the need for power stations. The forecasts are vital to long-range planning decisions. An expected increase of demand would lead to a sequence of capital expenditures. Underestimating the demand may create a shortage of installed capacity and thus a failure to provide needed service. This is certainly a violation of the cardinal principle of a utility which shall stand ready to give service to anyone who demands it without undue or unjust burden. On the other hand, premature expansion of facilities caused by an overestimate will lead to added costs. These considerations underline the importance of obtaining accurate forecasts of peak demand and energy consumption.

6.2. RECOMMENDATION

The following procedures to be implemented by Saudi Arabia to forecast energy consumption and peak demand on a short and long term basis are recommended as aid for planning purposes.

6.2.1 Make use of external data available to reflect future demographic, economic conditions and increases in oil production schedules.

6.2.2 Consider the effect of weather on the impact of historical growth in peak demand and energy consumption. |13-16|

6.2.3 Forecast by classes of service peak demands and energy send-out since they are interrelated quantities.

6.2.4 Consider forecast numbers as most probable results within a range of values rather than "point estimates". Although it is recognized that it is important for capacity planning purposes to make point estimates on one number, it is also important to recognize the conditions, both practical and probabilistic, associated with each forecast.

6.2.5 Computerize various elements in the forecasting function. Some computer applications should be:

A- Increased use of customer billing histories as an analytical tool. (Such data may be obtained from all power companies in Saudi Arabia).

B- Incorporation of these histories together with appliance surveys and load research results in specific tasks.

6.3. MICRO & MACRO FORECAST |19|

In order to ensure a rational and responsible forecast of both energy and peak demands, a multi-stage procedure should be followed.

First, independent energy projections for residential and industrial sales classification as well as aggregate demand projections should be made for the Saudi system.

Second, these projections should be interrelated for each of the years encompassed by the forecasts to assure:

1) proper relationship exists between the total Saudi Arabia system energy projections.

2) reasonable values in each case of the load factor, which relates the energy to the peak demand.

The Third step should entail the utilization of the aggregate Saudi Arabia system macro approach to perform a series of sensitivity analysis. The analysis would result in a set of reasonable forecasts of the electric demand and energy requirements, based on a range of variations in the assumptions on which the initial projections are established.

Finally, the peak demand and energy for each company operating in the Saudi system should be derived by using an allocation designed to maintain the same relative contribution to the aggregate Saudi system load as initially projected by the analytical micro models.

In addition, separate and independent analysis, which would focus on the effect exerted by demographic, economic, and meteorological forces on electrical energy use should be carried out on macro and micro bases.

The micro approach involves factors affecting load characteristics of each region or sector of the system. While considering such factors, the macro approach also recognizes the availability and applicability of certain data to specific geographical areas.

6.3.1 Micro Forecast: |17|

The following paragraphs discuss the methodology necessary for each component of the micro forecast for the Saudi system.

6.3.1-1 Residential Energy Forecast:

The residential energy consumption forecast for Saudi Arabia should be developed as the product of two independently forecasted components - the number of residential customers and the energy usage per customer

Consumption (Residential Customer) =

No. of residential customer X The energy usage per customer.

The first step in developing the forecast is to analyze the population served. Historical population data covering Saudi Arabia should be used in the estimates of expected birth, survival, and migration rates. These calculations provide the forecast of population to be served.

The next step is to forecast the average number of people per household. This is based on an analysis of historical trends, modified by anticipated demographic developments in the area. The expected population is combined with the population per household producing the number of households, which is assumed equal to the number of customers to be served by electricity.

To forecast electric consumption per customer, historical usage data of appliances such as air-conditioners, television sets, refrigerators, cloth dryers, and heaters are derived through estimates of consumption and saturation for each appliance. Regression analysis should be used to model historical patterns. These techniques consist of simple and multiple regression analysis, ordinary least-sequence curve fitting, and trending by compounded growth rate analysis.

Regression analysis should be used extensively in estimating relationships between each respective energy sales sector and selected economic, demographic, and meteorological factors. After a satisfactory model is developed, it may be assumed that the derived coefficients, relating the past independent indices to actual energy consumption, would remain constant over the projected time period. This assumption allows the projection of future energy sales to be made by using forecasted values of the corresponding independent variables. However, due to the inherent dynamic behavior of these coefficients over an extended period of time and the problems that might be associated with obtaining unbiased estimates of these parameters, this same assumption also limits the time horizon that the forecaster can use the model with any degree of confidence.

The remaining set forecasting techniques, which include ordinary least-squares curve fitting and trending by compounded growth-rate analysis, attempt to define the average rate of growth of a time-series over a long period of time. Generally, these forecasting techniques are not closely responsive to recent fluctuations in the growth pattern. To use these techniques with success, knowledge of such changes is needed as well as the nature of any forces causing the fluctuations, and their expected duration.

It is important to know whether recent changes in the growth pattern are indicative of a modification in the system's characteristics, and thus, represent a change which can be sustained. Also, a model from projected saturations of air-conditioners, water heater, ranges, and cloth dryers, should be developed together with an average consumption for each of these appliances. This technique considers historical acceptance rates for appliances, modified to reflect future increase in efficiency. Fig. 6.1 illustrates this approach.

Finally the forecast of residential energy is the product of the number of customers and their usage.

6.3.1-2 Industrial Energy Forecast:

The forecast of Saudi Arabia industrial energy consumption should be developed independently into components of the various segments of oil users and all other manufacturers Mathematical models should be derived by regression analysis of historical data. Statistical tests will determine any significant correlations between energy consumption with both indicators of various types of oil production and all other manufacturers. The energy usage components for the future are correlated from the models, applying independent forecasts of oil production and economic indicators. Finally, the sum of the two components constitutes the forecast of Saudi Arabia

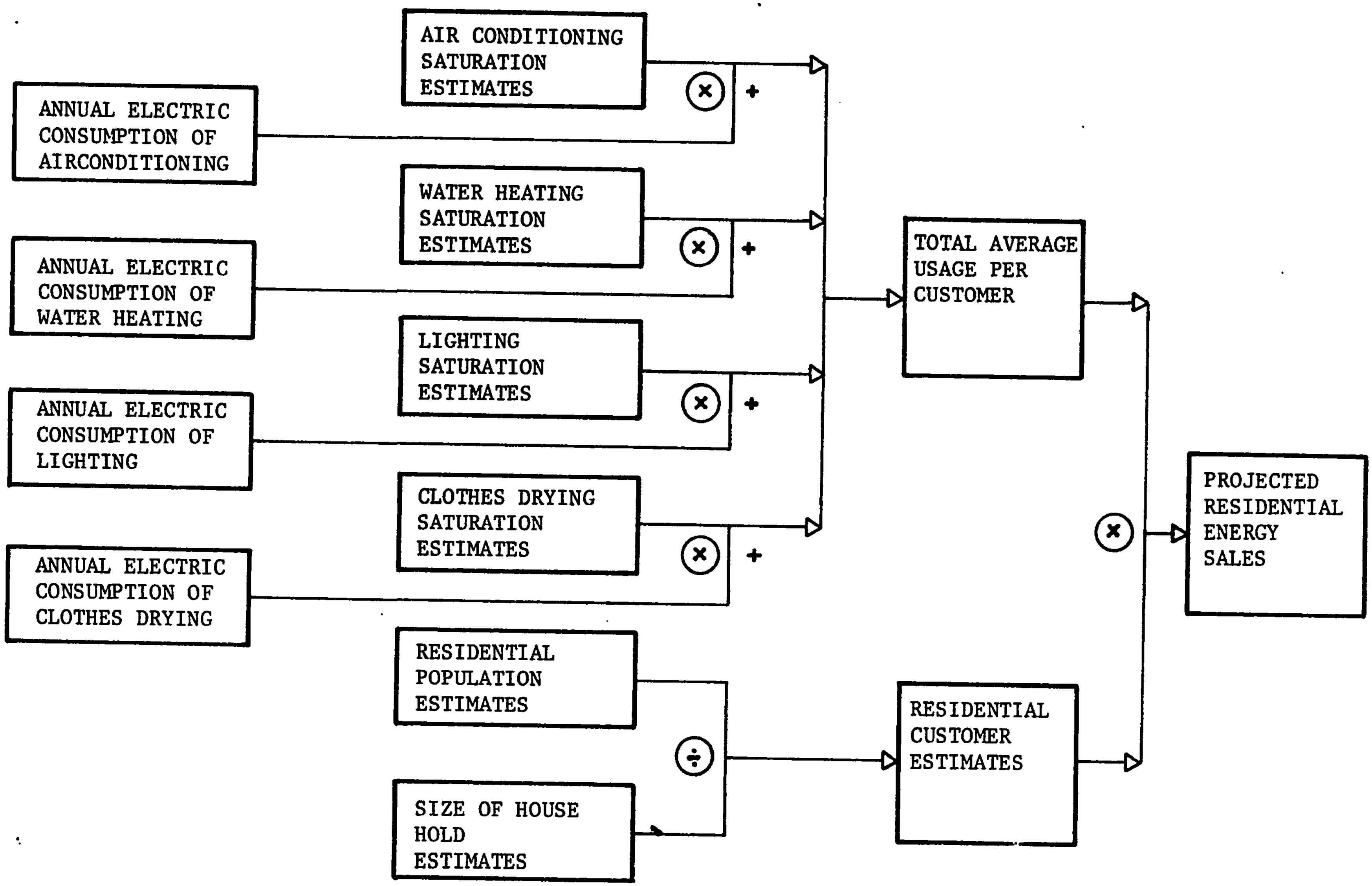


Figure 6.1. Saudi Arabia Residential Energy Sales Micro Model.

industrial energy consumption. Fig. 6.2 illustrates the industrial energy forecast.

6.3.1-3 Internal Energy Requirements:

The total internal energy requirements for Saudi Arabia are obtained by adding the respective projections of each energy classification: Residential and industrial, as well as energy losses.

6.3.1-4 Peak Demand Forecast:

The in-depth analysis of historical and projected energy consumption, as described above, form the basis for the peak demand forecast. As a first step, Saudi Arabia peak demand should be forecasted independently by analyzing historical data, making adjustments for weather conditions and oil production schedules, and applying various mathematical trending techniques. The resulting peak demand forecast should then be reconciled with the energy forecast, and necessary adjustments should be made so that it is consistent with anticipated load factors. The sum of demands forecasted may be adjusted to assume reasonableness and consistency. Future growth patterns in energy consumption, as established by the detailed energy forecast, are reflected in the demand forecast.

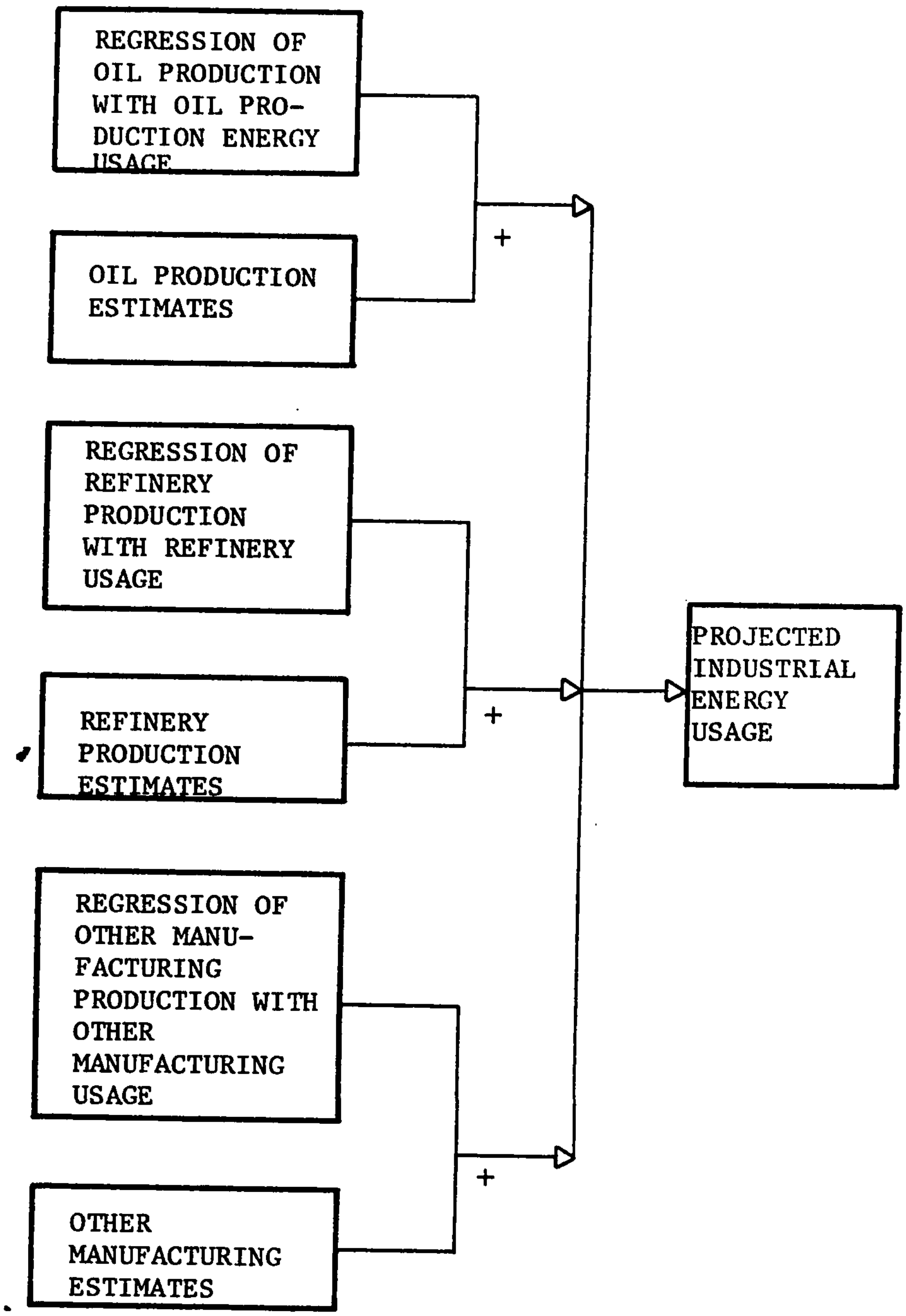


Figure 6.2. Saudi Arabia Industrial Energy Sales Micro Model.

6.3.2 Macro Forecast: |17|

This section presents the methods needed to develop the macro forecast of the Saudi Arabia system.

6.3.2-1 Residential Energy Forecast:

The Saudi Arabian system residential energy consumption model should involve determinations of the average use of Saudi Arabian customers. Projected energy consumption should be calculated for each group as the product of the average use per customer and the number of customers. These results are then added to obtain the total residential energy consumption.

The number of residential customers in each category is determined by applying a projection of new housing and a demographic analysis of Saudi Arabian population growth. Projection of average usage for Saudi Arabia should be based on a regression analysis of historical data.

6.3.2-2 Industrial Energy Forecast:

The Saudi Arabian system industrial energy consumption should be divided into two categories:

1. Oil sector
2. Other manufacturing sector.

For the oil sector, oil energy consumption should be based on a regression analysis of monthly oil productions. Other manufacturing energy usages are similarly determined except that the data series, selected for the utilization of the manufacturing capacity, should be representative of each manufacturing industry.

6.3.2-3 Peak Demand Forecast:

The analysis of various components of energy consumption should be used as a major input in the development of the demand forecast. The forecasting peak demand should be based on an analysis of historical growth rates. Projections of peak demand are then combined with the corresponding energy consumption to determine internal load factors.

6.4. THE RECOMMENDED METHODOLOGY

The recommended methodology shall forecast demand, energy and fuel for the periods of five, ten and twenty years. In addition the probability of actual demand being different from the forecasted demand shall be derived. Upper and lower limits of possible demand and energy values for chosen confidence levels shall be calculated over the entire range of forecast to the horizon year. The final projection to be used for planning purposes shall be clearly distinguished between those limits.

The best and fastest approach appears to be the integration of several existing forecasting schemes, into a new software package that would do the following:

6.4.1 The Five Year Forecast:

6.4.1-1 Accept as input and accumulate all known future industrial projects.

6.4.1-2 Accept as input: historical population growth, consumption rates and income; future population growth projections, consumption rates projection and income. Statistically project the residential portion of the load within the constraints of air conditioning, appliance and other saturation factors.

6.4.1-3 Using the information in 6.4.1-1, the historical expatriate consumption rate and income level, determine the project foreign population count and contribution to system peak and energy consumption within the proper constraints.

6.4.1-4 The commercial load presently is minimal and may be lumped with 6.4.1-2. However, a statistical subroutine shall be included to project this load as influenced by 6.4.1-2 and 6.4.1-3, when the commercial load becomes sizeable.

6.4.2 The Ten Year and Twenty Year Forecast:

The ten year and twenty year forecast shall rely heavily on any data inputted from known plans and projections and shall resort to statistical analysis if and when this type of data is insufficient. These projections shall also be governed by appropriate constraints.

In general the forecast output shall consist of two components medium term forecast and long term forecast.

The flow chart of Fig. 6.3, describes the desired approach to medium and long term forecasts. Since data inputs include both MW and MWH for all customer classes, it is envisioned that the same procedures apply for energy and demand independently. Then based on historical data, a load factor may be determined and used as constraint to ensure that the energy and demand projections are within reasonable confines.

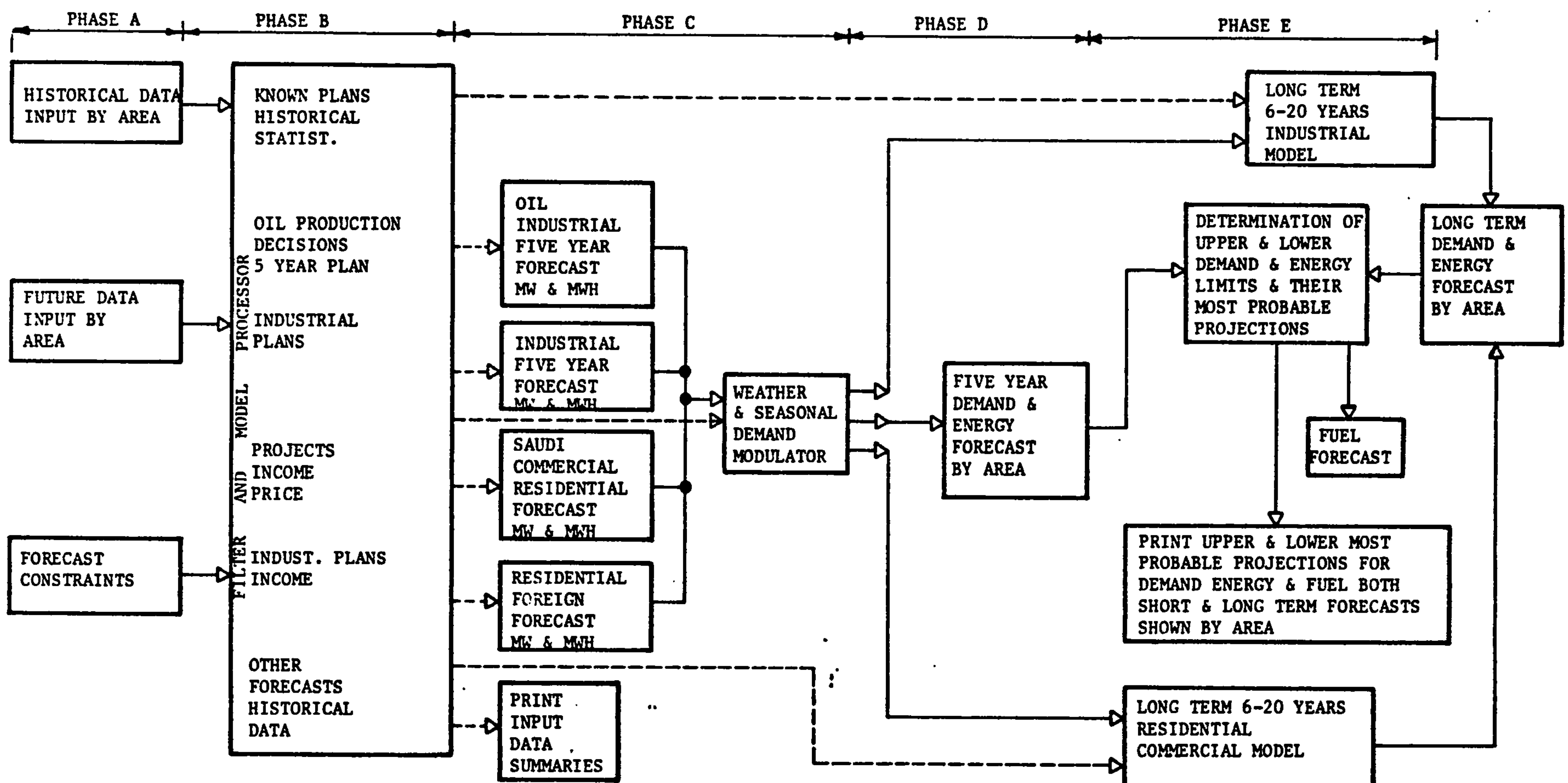


Figure 6.3. Saudi Arabia proposed method for forecasting MW and MWH.

6.4.3 Input Data, Phase A:

6.4.3.1 Historical data input:

This includes the following:

1. Industrial existing loads listed by year, area, location, substation or power plant, type of load, and connected horsepower.

2. Residential population and customer counts and total KWH billed listed by area, month, for the last ten years.

3. Commercial customer count and total monthly KWH billed listed by area for the last ten years.

4. Historical influence of new industrial loads on expatriate customer count, for the last ten years.

5. Monthly meteorological data for the last ten years.

6. Monthly MW peak demands for residential-commercial and industrial classes listed by area for the last ten years.

7. Peak demand with coincident data and time for some selected loads of each type of industrial load such as water injection, Gas Oil Separation Plants (GOSPS), etc.

8. Monthly MWH billed to industrial customer listed by type of load for the last ten years.

9. Historical oil production-demand and energy data.

6.4.3-2 Future Data Input:

This includes the following:

1. Industrial loads by connected horsepower, year, load type, location, area and substation or power plant.

2. Population projection by village, area, year, or year of service if not present, and projected maximum demand per customer.

3. Economic, demographic and other statistical data, by area.

4. Appliance consumption KWH listed by type of appliance.

5. Commercial customers by number, years of service and area.

6. Anticipated oil production plans.

7. Electrical energy-fuel conversion factors.

6.4.3-3 Constraints:

To include but not be limited to the following:

1. Population by year, area.

2. Air conditioning saturation by year, area.

3. Area demand or energy constraint, MW or MWH listed by year, area.

4. Appliance saturation by year, area.

5. Any forecasts available.

6. Confidence levels chosen to determine upper and lower values of forecasted demand.

6.4.4 Data Filter and Model Processor, Phase B:

At this point certain summaries of input data and print out should be prepared. These summaries shall be listed by:

1. Chronological order, for industrial customers only, showing date, customer name and connected horsepower.

2. Residential area present and future, each listed separately. Each listing shall show the town names listed alphabetically, the year, the population figures, and the maximum MW demand per customer.

3. Load type, for industrial customers only. Should be shown year, location, connected horsepower.

In addition, all other input and future data and constraints entered above shall be listed for verification.

Statistical analysis of historical and future data on income, price of energy, population projections, demography, etc. may be used to forecast the residential and commercial loads.

6.4.5 Weather and Seasonal Modulator, Phase C:

This may be one or more models applied to each of the customer class forecasts of Phase B above, to establish the monthly peak demands and energies. Historical data will be one source of data used to construct such a modulator. Ramadan is of a special nature and its effect on the loads should be recognized.

6.4.6 Five Year Forecast, Phase D:

The short term forecast should be saved at this point.

6.4.7 Long Term Forecast, Phase E:

Two models prepared during Phase B above may be applied at this point. The long term industrial model should resort to statistics for those years when no industrial plans were available.

The long term residential-commercial model should involve forecasts such as population, income, etc. entered under Phase A in its statistical structure.

6.5. BENEFITS TO SAUDI ARABIA

6.5.1 More accurate forecasts:

This is very important. In 1983, Saudi electric power generation is expected to exceed 6000 MW. A 10 per cent error means 600 MW costing over 2000 million Riyals (Capital Investment Only).

6.5.2 Assist in evaluating effect of forecast components:

6.5.3 Enable the forecasters to defend their forecasts:

When the validity of certain assumptions is in question, the forecaster shall have the ability to investigate the effect of varying these assumptions by varying the input data.

6.5.4 Assist in transmission planning:

Transmission planners need to know the expected demand in different areas. A reasonably accurate load forecast may be used for this purpose.

6.5.5 Provide energy and fuel forecasts:

This is particularly needed in determining revenues and costs.

6.5.6 A historical and future data:

Data bases will be established that will assist in supplying the government with the frequently required reports.

SUMMARY AND CONCLUSION

This study is basically concerned with the forecasting of the electric peak load in Saudi Arabia for the years (1978-2000).

At present, and well into the future, planned electric production fuel requirements exceed projected refinery capacity. Thus, electric generation in the Eastern Region during the coming years would use crude oil and natural gas. By 1988, it is probable that usage would shift to fuel oil and natural gas, provided that refinery capacity is expanded to meet the demand.

Also, the preferred fuels for the peak load generation such as combustion turbines and diesel generators are diesel oil, and where and when available natural gas.

It is found that by the year 2000, Saudi Arabia will have approximately 30,105 MW of electric peak load. In 1975, the peak demand was 800 MW. In 1978, the peak demand was 2223.5 MW. Over the next twenty two years period (1979-2000) the peak load will multiply nearly thirteen times for a compounded annual growth rate of 12%.

The types of generation which proved to be the most economic for supplying base load were central steam stations, combined electric generation and desalination plants. To be efficient, all of these units depend upon the availability of large quantities of water for cooling and condensing purposes. This water is only available in large quantities on the coast in the form of sea water.

The type of generating unit found to be most economic for supplying the peaking requirements of the interconnected system is combustion turbine. These units not only serve to supply peaking load, but can be located close to load centers and therefore reduce the need to transfer power on the transmission lines.

On the other hand, it should be mentioned that for such studies, the government has to establish a data - collecting capacity since peak load forecasts require up-to-date and precise statistic data. The lack of such capacity was one of the problems faced during this study.

It should also be mentioned that such peak load studies have to be reviewed every two to five years. Any new development plans proposed by the government whether necessity more electric power capacity than expected in this study or less, would undoubtedly affect the final results. The basic principles for improving this research work are given in chapter VI.

REFERENCES

|1| Abdel-Aal, H.K. & Schmedzlee, R. : "Petroleum Economics & Engineering", Moral Dekker, Inc., 1976, New York, U.S.A.

|2| Aramco, : "Aramco 1978 Saudi Arabia", 1979, Dhahran, S.A.

|3| Aramco, : "Facts & Figures 1978", 1979, Dhahran, S.A.

|4| Aramco, : "Ghazlan Power Plant", 1977, Ghazlan, S.A.

|5| Aramco, : "SCECO Annual Review of Operations 1978", 1979, Dhahran, S.A.

|6| Aramco Service Company, : "Load Forecast and Distribution - Subtransmission Planning Study For the Al-Hasa Oasis Through 1984", 1977, Houston, U.S.A.

|7| Asburg, C.E. : "Weather Load Model For Electric Demand & Energy Forecasting", IEEE Tran. on Power Apparatus & System, vol. PAS-94, No. 4, July/Aug. 1975.

|8| Brown, : "Solution of Large Networks by Matrix Methods", John Wiley & Sons, Inc., 1975.

|9| Brown, R.G. : "Smoothing, Forecasting and Prediction of Discrete Time Series", Prentice-Hall, Englewood Cliffs, 1963, N.J.

|10| Christiaanse, W.R., : "Short Term Load Forecasting Using General Exponential Smoothing", Trans. IEEE, Vol. PAS-90, No. 2, March/April 1971, pp. 900-910.

|11| Cleron, J.P. : "The Future of Saudi Arabia. A Long-Range Analysis of the Saudi Arabia Economic Development", U.P.M. Press, 1976, Dhahran, S.A.

|12| Coombe, R.A. : "Magneto Hydro Dynamic Generation of Electrical Power", Reinhold Publishing Corporation, 1964, New York, U.S.A.

|13| Corpening, S.L., Reppen, N.D., Ringlee, R.J., : "Experience With Weather Sensitive Load Models for Short & Long Term Forecasting", IEEE Trans. on Power Apparatus and Systems, vol. PAS-92, No. 6, Nov./Dec. 1973, pp. 1966-1972.

|14| Daney, J., Saack, J.J., Cunningham, G.W., and Priest, K.W. : "Practical Application of Weather Sensitive, Load Forecasting to System Planning", IEEE Trans. on Power Apparatus and Systems, vol. PAS-92, No. 3, May/June, 1973, pp. 971-974.

|15| Davey, : "Weather Sensitive Load Forecasting, Application to System Planning", IEEE Trans., vol. PAS-92, No. 3, May/June, 1973, pp. 975-977.

|16| Davies, M. : "The Relationship Between Weather and Electricity Demand", Proc. IEEE, vol. 106C, pp. 27-37, October 1958.

|17| Ebasco, : "Recommended Procedures for a Load Research Program and Forecasting Methodology for the Saudi Consolidated Electric Company",1977.

|18| Edison Electric Institute, : "Statistical Data Compiled in the United States of America", 1975.

|19| Electreco, : "Proposed Electrification Plan 1980-1985", 1978, Riyadh, S.A.

|20| Fajkus, D., : "Forecast Method Removes Weather Bias", Public Service Board Tex. U.S.A., 1975.

|21| IEEE Std., : "Electric Power Distribution for Industrial Plants", 1969.

|22| Industrial Studies & Development Center, : "A Guide to Industrial Investment in Saudi Arabia", 1977.

|23| Kettani, M. Ali, : "The Energy Problem, Present Situation & Future Alternatives for the Gulf Region", The Gulf Conference, 1978.

|24| Kettani, M. Ali, : "Solar Energy for the Development of Arid Zones", Conference on Alternate Energy Sources, 1978, Rabat, Morocco.

|25| Main's, C.T., : "Long Term Electrification Plan For the Kingdom of Saudi Arabia", 1977, Riyadh, S.A.

|26| Manufacturers Description, : "Electrical Power Generation", 1976, U.S.A.

|27| Mashayekhi, A.N., : "Strategy of Economic Development In Iran", System Dynamics Group, M.I.T., U.S.A., 1977.

|28| Ministry of Planning, : "First Development Plan 1970-1975", 1969, Saudi Arabia.

|29| Ministry of Planning, : "Population Projections", 1974, Saudi Arabia.

|30| Ministry of Planning, : "Second Development Plan 1975-1980", 1974, Saudi Arabia.

|31| Reward, W., : "Development of A Five-Year Forecast of Peak Electrical Demand", Sacramento State College, 1966, U.S.A.

|32| Riggs, James L., : "Production Systems Planning, Analysis, and Control", John Wiley & Sons, Inc., 1976.

|33| Sheppard & Williams, : "Solar Energy Research and Development & Educational Services For Arab Nations", 1976, Georgia Tech., Atlanta, U.S.A.

|34| Singh, P., : "House Hold Survey Methodology In Saudi Arabia", DAA-SWCC, 1978, Riyadh, S.A.

|35| Sommerfield, C., : "Forecasting Load Growth", The Toledo Edison Co., 1974, U.S.A.

|36| Srinirasan, K. & Pronovost, R., : "Short Term Load Forecasting Using Multiple Correlation Models", IEEE Tran. on Power Apparatus & Systems, vol. PAS-94, No. 5, Sept./Oct. 1975, pp. 1854-1858.

|37| Stanton, K.N., and Gupta, P.C., "Forecasting Annual or Seasonal Peak Demand In Electric Utility Systems" Trans. IEEE, vol. PAS-89, May-June 1970, pp. 951-959.

|38| Starr, A.T., : "Generation, Transmission & Utilization of Electrical Power", Sir Issac Pitman & Sons Ltd., London, 1969, U.K.

|39| Sullivan, R.L., "Power System Planning", McGraw-Hill, Inc., 1977, U.S.A.

|40| SWCC, : "Desalination and Power Plants Operating or Planned For Construction in the Kingdom of Saudi Arabia", 1978, Jeddah, S.A.

|41| Toyoda, J., Chen, M., and Inow, Y., : "An Application of State Estimation to Short-Term Load Forecasting", Trans. IEEE, vol. PAS-89, Sept./Oct. 1970, pp. 1678-1682 and 1683-1688.

APPENDIX A

OIL PRODUCT CONSUMPTION IN SAUDI ARABIA

(Quantity shown in 42 US Gallon/Barrels)

Product	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Regular Gasoline	1,426,264	1,546,810	1,678,045	1,742,569	2,016,188	2,268,544	2,505,956	2,762,558	2,793,053	2,443,799
Premium Gasoline	452,420	583,701	667,419	744,271	907,902	1,253,888	1,863,138	3,083,644	5,036,540	7,646,459
Diesel Fuel	1,903,427	1,958,750	2,198,441	2,323,382	2,877,185	3,701,476	4,681,705	6,034,915	9,308,864	14,861,233
Kerosene	399,417	444,989	442,356	495,608	581,006	669,038	671,258	676,535	588,463	526,862
L. P. G.	-	399,561	470,440	555,123	671,766	831,614	1,046,560	1,088,970	1,031,569	1,376,855
Lubricants	25,021	33,144	32,696	31,803	35,208	49,331	61,113	79,681	108,547	121,094
Turbo Fuel A-1	317,993	411,017	491,620	533,658	606,229	682,523	1,069,428	1,365,626	2,038,630	3,018,365
Aviation Gasoline 100/130	28,712	27,831	29,738	30,901	25,878	21,436	22,327	15,577	5,780	6,006
Aviation Gasoline 115/145	16,996	11,980	7,471	-	-	-	-	-	-	-
Jet Fuel JP-4	70,403	48,290	49,678	47,158	48,790	74,273	78,321	76,585	70,528	75,346
Aviation Gasoline 80/87		-	-	237	561	506	503	597	472	402
Miscellaneous	12,491	16,409	15,491	16,243	11,502	15,797	14,082	17,333	13,296	12,937
Crude Oil	-	-	-	-	-	-	353,931	2,140,761	2,932,101	3,631,686
Penetrating Asphalt 60/70	-	-	-	-	-	-	63,812	245,822	270,209	1,022,478
Bunkering	-	-	-	-	-	-	-	-	1,367,205	5,215,849
Total	4,653,144	5,482,482	6,083,395	6,520,953	7,782,215	9,568,426	12,432,134	17,588,604	25,565,257	39,959,371
Increase	-	829,338	600,913	437,558	1,261,262	1,786,211	2,863,708	5,156,470	7,976,653	14,394,114
Percent	-	18%	11%	7%	19%	23%	30%	41%	45%	56%

* Source Petromin - Dhahran - Saudi Arabia, 1978

APPENDIX B: *

1394 Census of Population

POPULATION OF SAUDI ARABIA BY ADMINISTRATIVE REGION, 1394 A.H

ADMIN REGION	POPULATN CENTER	NO OF HOUSEHLD	POPULATN SETTLED	POPULATN MIGRANT	TOTAL
RIYADH	1 992	198 936	965 805	306 470	1272275
MECCA	4 088	325 789	1513634	240 474	1754108
EASTERN REGION	667	120 684	690 188	79 460	769 648
ASIR	4 597	127 131	434 884	246 477	681 361
MEDINA	1 742	98 835	282 195	237 099	519 294
JAZAN	4 537	85 483	387 161	15 945	403 106
QASIM	509	48 724	215 447	101 193	316 640
HAYIL	540	45 338	117 210	142 719	259 929
TABUK	472	33 642	105 388	88 375	193 763
AL BAHAH	1 296	34 323	156 997	28 908	185 905
NAJRAN	242	26 569	91 555	56 415	147 970
NORTHERN BORDERS	130	19 345	42 666	86 079	128 745
AL JAWF	85	10 243	34 093	31 401	65 494
QARYAT	98	5 873	18 432	12 972	31 404
BEDOUIN ON BORDERS	-	30 000	-	210 000	210 000
SAUDIS ABROAD AT TIME OF CENSUS	-	-	73 000	-	73 000
TOTAL	20 995	1210915	5128655	1883987	7012642

* Source : Ministry of Planning, Riyadh, Saudi Arabia.

MAJOR CITIES OF SAUDI ARABIA ARRANGED
BY NUMBER OF POPULATION, 1394 A.H

CITY	ADMIN REGION	NO OF HOUSEHLD	NO OF POPULATN
RIYADH	RIYADH	101 506	666 840
JEDDAH	MECCA	97 363	561 104
MECCA	MECCA	67 947	366 801
TAIF	MECCA	30 877	204 857
MEDINA	MEDINA	35 390	198 186
DAMMAM	E REGION	21 513	127 844
HOEUF	E REGION	14 551	101 271
TABOUK	N REGION	10 696	74 825
BURAYDAH	QASIM	8 774	69 940
AL MUBARRAZ	E REGION	7 775	54 325
KHAMIS MUSHAYT	ASIR	8 142	49 581
AL KHOBAR	E REGION	9 023	48 817
NAJRAN	NAJRAN	9 149	47 501
HAYIL	HAYIL	6 065	40 502
JAZAN	JAZAN	5 648	32 812
ABHA	ASIR	5 413	30 150

POPULATION OF RIYADH REGION 1394 A.H.

EMIRATE	NO OF CENTERS	NO OF HOUSEHLD	SETTLED POPULATN	MIGRANT POPULATN	TOTAL
CITY OF RIYADH	1	101 506	665 325	1 515	666 840
IRQAH	6	245	1 651	114	1 765
DARIYAH					
CENTER OF EMIRATE	9	857	5 542	-	5 542
AL AMAREYAH	6	143	672	309	981
TOTAL	15	1 000	6 214	309	6 523
AYEENAH & JUBAILAH	9	355	1 703	426	2 129
BUNBAN	5	11	50	-	50
RUMAH	23	2 199	2 621	10 992	13 613
HURAYMILA					
CENTER OF EMIRATE	1	565	3 852	18	3 870
SALBOUKH	2	50	224	126	350
HAZWA	2	7	41	-	41
SADOUS	1	57	290	-	290
GHAYANAH	2	2	24	-	24
MULHAM	3	100	424	84	508
GARINA	1	60	280	-	280
BARRAH	7	127	420	312	732
TOTAL	19	968	5 555	540	6 095
THADIQUE					
CENTER OF EMIRATE	15	642	3 503	450	3 953
DUGLAH	2	25	56	57	113
THADIQUE					
SAFRAT	1	75	500	-	500
RAGHBA	8	362	593	438	1 031
BIR	2	74	390	-	390
TOTAL	28	1 178	5 042	945	5 9[illegible]
MAJMA'AH					
CENTER OF EMIRATE	23	1 738	7 687	3 921	11 608
HURMA	1	135	802	-	802
JALAJIL	8	355	1 619	252	1 871
RAWDAH SUDAYR	1	241	1 538	57	1 595
MI'SHABA	1	8	47	-	47
TWAIM	1	86	462	27	489
DAKHELAH	1	21	156	12	168
HUSOON	1	28	162	-	162
HOWTAT SUDAYR	4	419	2 336	90	2 426
JANOBEYAH	1	87	475	-	475
JUNAIFY	1	16	104	-	104
ATTAR	1	61	382	-	382
AL OUDAH	3	210	646	420	1 066
KHUTAMAH	1	98	751	-	751
ASHIRAT SUDAIR	1	99	826	-	826
TAMEER	23	954	3 331	3 057	6 388
ARTAWIYAH	22	1 980	2 740	7 779	10 519
JERAB	5	769	227	3 633	3 860
RUWAYDAH	1	45	61	216	277
KHAIS	1	46	77	252	329
AL FURUTHI	4	58	44	318	362
TOTAL	105	7 454	24 473	20 034	44 507

AL GHAT					
CENTER OF EMIRATE	10	869	2 138	1 575	3 713
MULAIH	1	83	433	9	442
TOTAL	11	952	2 571	1 584	4 155
AL ZULFI					
CENTER OF EMIRATE	116	2 655	15 683	5 058	20 741
SAMNAN	2	13	158	-	158
UGLAH	1	112	881	-	881
THWAIR	1	25	214	-	214
TOTAL	120	2 805	16 936	5 058	21 994
SHAQRA					
CENTER OF EMIRATE	11	1 312	6 458	1 374	7 832
ASHAIGER	8	391	762	1 269	2 031
FARHAH	2	14	55	36	91
DAHENAH BADEYAH	5	155	403	420	823
DAHENAH HADERAH	3	13	62	-	62
HARIQ	3	74	308	90	398
MESHASH AL ABD	3	51	276	-	276
QASSAB	10	222	1 045	63	1 108
WAKF	1	58	241	-	241
GHASSLAH	3	323	328	1 377	1 705
SHAQRA					
JURAIFAH	2	21	96	-	96
TRAVELLERS	-	-	7 459	-	7 459
TOTAL	51	2 634	17 493	4 629	22 122
MURAT					
CENTER OF EMIRATE	29	1 322	3 016	4 926	7 942
ATHITHEYAH	6	62	382	-	382
THARMADA	5	176	925	-	925
TOTAL	40	1 560	4 323	4 926	9 249
DARMA					
CENTER OF EMIRATE	13	840	3 919	1 953	5 872
WUSTA	1	45	281	-	281
TOTAL	14	885	4 200	1 953	6 153
AL MUZAHMEYAH	21	1 152	4 811	2 372	7 183
AL GHATGHAT	2	278	1 676	-	1 676
AL HAIR	7	491	2 530	672	3 202
AL KHARJ					
CENTER OF EMIRATE	63	6 680	37 796	4 551	42 347
SAMEYAH	6	504	3 233	-	3 233
YAMAMAH	2	636	4 230	90	4 320
HAYATHIM	4	599	3 272	903	4 175
N'AJAN	4	612	3 943	327	4 270
DILAM	14	2 270	14 497	1 008	15 505
TOTAL	93	11 301	66 971	6 879	73 850

HOWTAT BENI TAMIM					
CENTER OF EMIRATE	35	2 793	10 302	5 337	15 639
ATTYAN	1	87	515	-	515
QU'AI	1	176	907	-	907
HALWA	1	452	2 760	-	2 760
TOTAL	38	3 508	14 484	5 337	19 821
HARIQ					
CENTER OF EMIRATE	36	974	3 526	2 601	6 127
NAA'M	2	331	1 948	-	1 948
TOTAL	38	1 305	5 474	2 601	8 075
AL AFLAJ					
CENTER OF EMIRATE	58	3 400	13 169	6 423	19 592
NORTHERN BADI'	30	805	1 848	2 463	4 311
SOUTHERN BADI'	2	53	236	63	299
HOMMAR	7	584	1 992	912	2 904
HADAR	27	819	1 912	2 133	4 045
TOTAL	124	5 661	19 157	11 994	31 151
AL SULAYYIL					
CENTER OF EMIRATE	15	2 026	6 076	6 150	12 226
RAYDA	1	413	1	2 853	2 854
UM AL ALGA	1	1 072	781	8 844	9 625
TRAVELLERS	-	-	727	-	727
TOTAL	17	3 511	7 585	17 847	25 432
WADI AD DAWASIR					
CENTER OF EMIRATE	209	3 945	14 992	17 151	32 143
NWAIMAH	1	458	2 514	123	2 637
TOTAL	210	4 403	17 506	17 274	34 780
AD AWADIMI					
CENTER OF EMIRATE	86	6 233	17 435	22 407	39 842
SAJER	9	1 739	3 756	6 783	10 539
ARTAWI	4	305	1 619	174	1 793
FAIDAH	2	229	1 195	126	1 321
SAKRAN	1	32	163	-	163
AIN AL SWAINA	1	44	194	-	194
AIN BEN QANOVR	1	74	362	-	362
BOROUD	3	134	421	459	880
MUSHREF	1	8	50	-	50
ATHLAM	4	94	640	-	640
NAFY	60	2 650	3 905	11 256	15 161
JAMSH	52	2 006	6 091	5 412	11 503
RASHAWEYAH	2	38	142	102	244
AL QA'EYAH	29	2 439	1 776	10 464	12 240
BIJADIYAH	9	530	1 261	1 665	2 926
ASH SHA'RA	20	958	990	4 761	5 751
TOTAL	284	17 513	40 000	63 609	103 609

AL QUWAE'IYAH					
CENTER OF EMIRATE	99	2 486	5 284	8 835	14 119
RAIN	174	2 696	5 862	8 853	14 715
MAZ'IL	11	302	1 811	27	1 838
RUWAYDAH	138	4 278	5 186	20 202	25 388
TOTAL	422	9 762	18 143	37 917	56 060
AFIF	181	10 926	8 707	57 654	66 361
AL KHASORAH					
CENTER OF EMIRATE	91	4 733	312	25 896	26 208
HALBAN	17	640	292	3 393	3 685
TOTAL	108	5 373	604	29 289	29 893

POPULATION OF MECCA REGION, 1394 A.H

EMIRATE	NO OF CENTERS	NO OF HOUSEHLD	SETTLED POPULATN	MIGRANT POPULATN	TOTAL
CITY OF MECCA	- 1	67 947	366 012	789	366 801
MECCA					
CENTERS REPORTING TO					
MECCA GOVERNOR	18	648	2 011	1 101	3 112
SHADAD	45	1 139	3 404	2 256	5 660
BIJAIDI	18	531	1 086	1 116	2 202
BAHRAH	16	1 279	5 782	1 266	7 048
DAFFAG	20	954	41	4 809	4 850
UM AR RAKAH	25	638	1 176	1 620	2 796
SA'YA	7	211	679	174	853
BAYDA	10	376	311	999	1 310
SA'DEYAH	5	428	71	1 587	1 658
TOTAL	164	6 254	14 561	14 928	29 489
HUDA	10	548	2 791	-	2 791
JEDDAH GOVERNOR					
CITY OF JEDDAH	1	97 363	560 984	120	561 104
CENTERS REPORTING					
TO CITY	27	724	3 943	21	3 964
THAHBAN	24	598	1 826	1 152	2 978
TOTAL	52	98 685	566 753	1 293	568 046
RABIGH					
CENTER OF EMIRATE	9	1 888	7 688	822	8 510
QADHIMA	12	861	2 528	849	3 377
THAOL	5	859	2 569	534	3 103
NWAIB'E	9	1 080	58	4 233	4 291
MASTURAH	11	749	2 284	708	2 992
HAJR	17	1 343	1 405	4 077	5 482
ABWA	33	742	2 921	462	3 383
TOTAL	96	7 512	19 453	11 685	31 138
AL THAYBA					
CENTER OF EMIRATE	28	1 200	2 921	2 109	5 030
BURAIKAH	14	1 331	151	5 136	5 287
SALIM	16	951	1 460	2 997	4 457
TOTAL	58	3 482	4 532	10 242	14 774
AL KHULAIS					
CENTER OF EMIRATE	7	2 962	10 417	1 929	12 346
UM AL JURM	4	359	1 388	39	1 427
BARZAH	13	1 151	2 462	1 848	4 310
TOTAL	24	4 472	14 267	3 816	18 083
AL KAMEL					
CENTER OF EMIRATE	69	2 755	5 068	5 436	10 504
HORRAT ZURAH	17	814	818	3 267	4 085
GHARIF					
AL TARAJMAH	13	984	2 346	252	2 598
TOTAL	99	4 553	8 232	8 955	17 187

MEDRAKAH					
CENTER OF EMIRATE	19	1 076	1 283	3 318	4 601
RAHAT	15	578	988	1 296	2 284
QAFIF	17	728	1 138	2 283	3 421
TOTAL	51	2 382	3 409	6 897	10 306
AL JOMQUM					
CENTER OF EMIRATE	26	2 857	11 704	1 500	13 204
RAYAN	13	442	1 265	456	1 721
ASFAN	18	1 016	2 580	270	2 850
AIN SHAMS	5	311	1 084	603	1 687
HADA AL SHAM	6	613	2 346	177	2 523
FAWARAH	5	566	10	2 280	2 290
TOTAL	73	5 805	18 989	5 286	24 275
AL SHARAI'					
CENTER OF EMIRATE	8	441	2 638	-	2 638
JURANA	4	106	95	384	479
TOTAL	12	547	2 733	384	3 117
AL MEDYEG	14	600	2 048	132	2 180
AL ZAIMA	19	866	2 809	1 194	4 003
AL TAYIF					
TAYIF CITY	1	30 877	203 981	876	204 857
TAYIF SUBRUBS	292	13 719	44 692	33 360	78 052
HADA	45	1 325	7 135	273	7 408
SAIL	14	734	2 076	2 598	4 674
ASHIRAH	16	1 554	2 268	5 796	8 064
SHAFA	66	1 116	5 804	144	5 948
QIBA	14	2 031	516	9 831	10 347
ABO RAKAH	22	2 429	121	13 026	13 147
BENI SAD	59	2 853	12 797	1 197	13 994
MESAN	131	2 957	13 909	2 082	15 991
THAGIF	35	832	4 745	-	4 745
HADDAD BEN MALIK	128	1 629	10 604	12	10 616
QAVEE'	171	2 064	12 198	-	12 798
TOTAL	994	64 120	320 846	69 195	390 041
AL MOYAH AL JADEED					
CENTER OF EMIRATE	31	1 696	2 639	7 503	10 142
AL MOYAH AL QADEEM	1	1	4	-	4
DUAIBEJAH	1	106	341	249	590
HAFAR	6	325	347	1 506	1 853
TOTAL	39	2 128	3 331	9 258	12 589
AL QAREE'					
CENTER OF EMIRATE	7	840	366	3 600	3 966
AL MAHATHI	29	1 171	845	5 211	6 056
TOTAL	36	2 011	1 211	8 811	10 022
TURABAH					
CENTER OF EMIRATE	67	7 125	9 126	30 012	39 138
AL HASHRAJ	1	200	396	564	960
TOTAL	68	7 325	9 522	30 576	40 098

AL KHURMAH					
CENTER OF EMIRATE	72	3 238	9 438	9 102	18 540
AL GHARIF	5	651	2 545	1 674	4 219
TOTAL	77	3 889	11 983	10 776	22 759
DHULAM					
CENTER OF EMIRATE	6	383	434	1 758	2 192
AL HAFIRAH	2	66	-	378	378
TOTAL	8	449	434	2 236	2 570
AL DAFINAH	49	1 037	472	5 466	5 938
AL LITH					
CENTER OF EMIRATE	18	835	3 168	-	3 168
AL GHALA	17	259	1 307	-	1 307
LA'LAM	25	413	1 675	-	1 675
GHAMIGAH	161	1 647	6 889	165	7 054
AL SHAWAG	87	2 161	6 451	1 794	8 245
AL JAEZAH	361	1 462	5 726	1 302	7 028
ADHAM	256	2 859	9 904	2 766	12 664
BENI YAZEED	28	952	188	4 818	4 966
TOTAL	953	10 588	35 208	10 839	46 047
	925	9,636	35,120	6,021	41,141
AL QUNFUDAH					
CENTER EMITATE	42	2 586	10 368	-	10 368
GOUZ	76	3 291	12 472	-	12 472
HALY	97	3 643	14 191	-	14 191
HARB & BENI ABS	110	1 858	6 053	1 239	7 292
MUDHAILEF	86	2 802	10 272	174	10 446
QADEEH	36	1 149	4 261	-	4 261
NORTH ARADEYAH	308	4 995	15 450	6 159	21 609
SOUTH ARADEYAH	213	4 363	17 816	2 484	20 300
TOTAL	968	24 687	90 883	10 056	100 939
AL BERK					
CENTER OF EMIRATE	91	797	3 656	330	3 986
THAHBAN	11	114	426	-	426
OMGUE	11	244	931	-	931
TOTAL	113	1 155	5 013	330	5 343
RANYAH					
CENTER OF EMIRATE	57	1 525	7 459	873	8 332
AMLAH	63	3 222	683	16 557	17 240
TOTAL	120	4 747	8 142	17 430	25 572
TOTAL MECCA REGION	4 088	325 789	1513634	240 474	1754108

POPULATION OF EASTERN REGION, 1394 A.H

EMIRATE	NO OF CENTERS	NO OF HOUSEHLD	SETTLED POPULATN	MIGRANT POPULAIN	TOTAL
DAMMAH	1	21 513	127 418	426	127 844
KHOBAR	3	9 033	48 703	114	48 817
THUGBAH	2	4 299	27 455	27	27 482
DHAHRAN	3	5 692	16 282	-	16 282
ABQAIQ	50	4 831	21 805	3 003	24 808
AIN DAR	30	1 362	1 402	8 274	9 676
QATIF	27	11 483	87 868	780	88 648
SAIHAT	3	2 702	22 205	45	22 250
SAFWA	19	2 672	20 657	357	21 014
RAHIMAH	5	3 908	21 162	21	21 183
AL JUBAIL	21	1 171	6 421	1 020	7 441
AL NAMAIREYAH	54	1 207	1 786	6 342	8 128
NITA'	71	1 219	4 234	4 527	8 761
QARYAT	25	1 731	4 580	6 357	10 937
AL SAFANIYA	36	1 102	1 411	4 593	6 004
AL KHAFJI	13	2 631	12 122	1 434	13 556
AL RAQSA	15	625	850	1 428	2 278
HAFAR	15	3 474	12 088	11 112	23 200
QAISUMAH	2	528	2 821	801	3 622
AL AHSA					
HOFUF	1	14 551	101 244	27	101 271
MUBARRAZ	1	7 775	54 271	54	54 325
QARI AL AHSA	74	10 944	74 688	4 419	79 107
UYUN	7	1 381	9 545	174	9 719
TRAVELLERS	-	-	2 984	308	3 292
TOTAL	83	34 651	242 732	4 980	247 712
AL AQIR	12	109	107	567	674
SALWA	78	1 304	889	7 059	7 948
AL ADHILEYAH	8	315	2 459	381	2 840
AL HANI	3	280	90	1 827	1 917
HARDH	83	1 757	2 246	7 143	9 389
KHURAIS	2	814	101	5 412	5 513
MA'QALA	3	272	294	1 428	1 722
TOTAL	667	120 684	690 188	79 460	769 648

POPULATION OF ASIR REGION, 1394 A.H

EMIRATE	NO OF CENTERS	NO OF HOUSEHLD	SETTLED POPULATN	MIGRANT POPULATN	TOTAL
ABHA					
CITY OF ABHA	1	5 413	30 084	66	30 150
ABHA SUBURBS	413	5 487	24 854	7 155	31 209
KHAMIS MUSHAYT					
CITY OF KHAMIS	1	8 142	49 572	9	49 581
CENTER ATTACHED TO KHAMIS	113	3 874	15 400	6 672	22 072
TOTAL	114	12 016	64 972	6 681	71 653
UHUD RAFIDAH	91	4 396	19 516	5 589	25 105
SHA'AF SHAHRAN	84	1 931	7 499	3 240	10 739
SURAT OBIEDAH	131	3 900	18 905	3 996	22 901
WADI BEN HASHBAL	119	1 689	3 041	6 876	9 917
BA'RA	127	1 903	3 301	6 957	10 258
AL ARIN & TAREEB	76	1 674	4 099	4 665	8 764
AL MODHAH	44	1 957	1 872	9 135	11 007
AL AMWAH	66	2 635	41	15 333	15 374
AL AIN	26	1 190	138	6 549	6 687
TATHLITH	117	4 790	3 551	21 237	24 788
DHAHRAN AL JANOUB	256	5 317	18 893	10 368	29 261
AL JAWAH	30	951	280	5 523	5 803
AL FARSHAH	21	1 928	66	10 098	10 164
BALLAHMAR	156	2 119	7 436	4 284	11 720
BALLASMAR	129	1 923	8 366	1 494	9 860
TANUMA Beni Shahr	96	1 972	8 258	2 985	11 243
AN NAMAS	206	4 427	20 129	4 083	24 212
BENI AMR	155	2 142	10 986	6 678	17 664
RAJAL ALMA'	380	6 444	24 707	8 415	33 122
MAHAYEL	409	6 722	18 529	13 836	32 365
AL MUTARDAH	407	7 821	30 493	4 020	34 513
BAREK	77	3 425	10 717	3 477	14 194
AL FATIHAH	9	1 048	935	4 245	5 180
QANA & AL BAHR	226	4 119	14 760	4 278	19 038
KHAMIS MUTAIR	132	2 039	8 485	105	8 590
BISHAH	48	6 961	29 267	12 273	41 540
HAZMI	30	3 702	6 490	10 827	17 317
TABALAH	35	2 759	3 768	10 233	14 001
SAMKH	41	2 874	1 240	14 004	15 244
KHAIBER	38	1 522	2 880	5 223	8 103
AL SALMAH	3	160	1 004	-	1 004
AL QUR'AH	16	665	2 653	1 626	4 279
ALYAYAN & KHATHAM	90	1 675	7 216	2 667	9 883
BASHOOT	60	1 000	4 883	453	5 336
SABT AL ALAYA	138	3 435	1 1370	7 803	19 173
TOTAL BISHAH	499	24 753	70 771	65 109	135 880
TOTAL ASIR REGION	4 597	127 131	434 884	246 477	681 361

POPULATION OF MEDINA REGION, 1394 A.H

EMIRATE	NO OF CENTERS	NO OF HOUSEHLD	SETTLED POPULATN	MIGRANT POPULATN	TOTAL
MEDINA	1	35 390	197 949	237	198 186
AL MULALIEH	43	1 615	1 016	7 977	8 993
KHAYBER	73	6 813	6 578	25 638	32 216
AL 'ULA					
CENTER OF EMIRATE	76	3 161	7 590	10 128	11 718
ATHIB	6	321	362	1 368	1 730
MADAIN SALIH	25	858	400	3 780	4 180
JEDDAH	22	544	233	2 478	2 711
SULAILAH	11	116	520	39	559
AL HAJR AL THALATH	14	227	736	525	1 261
NASHAIFA	24	693	488	3 303	3 791
ABU RAKAH	15	645	593	3 018	3 611
FARE'AH	28	1 121	217	6 168	6 385
MUGHAYRA	13	805	1 670	2 706	4 376
ABRAK	9	38	89	117	206
TOTAL AL'ULA	243	8 529	12 898	33 630	46 528
ABYAR AL MASHY	33	4 090	1 472	17 913	19 385
WADI AL FARI'	84	2 556	2 776	9 498	12 274
SUWAYDIRAH	75	1 550	3 187	5 628	8 815
AL HANAKEYAH					
CENTRE OF EMIRATE	39	2 314	734	12 234	12 968
AN NAKHEEL	28	1 170	2 810	3 285	6 095
ARJA	26	994	358	5 256	5 614
TOTAL	93	4 478	3 902	20 775	24 677
AL MAHED					
CENTER OF EMIRATE	64	1 651	3 095	6 669	9 764
AL UMG	15	640	113	4 149	4 262
THARB	48	1 026	257	7 143	7 400
SUAIRFEYAH	29	595	2 219	1 707	3 926
SAFEINAH	39	442	475	2 493	2 968
ARN	22	295	1 262	492	1 754
AL FASHEYAH	11	361	181	1 542	1 723
HATHA	10	328	232	1 719	1 951
AL ASSAYHER	12	104	218	171	389
AL SA'ABEYAH	36	308	340	1 581	1 921
TOTAL	286	5 750	8 392	27 666	36 058
AL HASSO	39	1 455	3 307	5 319	8 626
AL FARISH	52	2 433	1 481	9 798	11 279
BADR					
CENTRE OF EMIRATE	104	3 918	6 790	11 238	18 028
AL WASITA	82	1 919	3 166	4 908	8 074
MUSAIJEED	91	1 893	2 621	5 391	8 012
AL KAHA	89	1 806	504	7 251	7 755
AL RAYES	11	288	630	669	1 299
TOTAL	377	9 824	13 711	29 457	43 168

YANBU'					
CENTER OF EMIRATE	15	3 145	15 960	1 443	17 403
AS SALEEM	9	206	34	1 113	1 147
AL JABREYAH	27	1 272	2 204	3 456	5 660
YANBU' AN NAKHL	38	4 238	3 328	15 879	19 207
AL AIS	90	1 912	2 712	6 507	9 219
AL MURABBA'	42	859	709	3 393	4 102
NABT	32	1 428	124	5 823	5 947
SHAJWA	90	1 292	456	5 949	6 405
TOTAL	343	14 352	25 527	43 563	69 090
TOTAL MEDINA REGION	1 742	98 835	282 195	237 099	519 294

POPULATION OF JAZAN REGION, 1394 A.H

EMIRATE	NO OF CENTERS	NO OF HOUSEHLD	SETTLED POPULATN	MIGRANT POPULATN	TOTAL
JAZAN CITY	1	5 648	32 812	-	32 812
BALGHAZI	883	1 893	8 470	321	8 791
BENI MALEK	870	2 341	10 464	-	10 464
FIFA	216	2 770	11 966	774	12 740
AL HASHR	148	727	2 129	822	2 951
SABYA	314	13 516	58 006	3 279	61 285
ASHAQIQ	32	1 048	4 801	-	4 801
AL QAHMA	27	488	2 149	99	2 248
AL ALYA	22	1 539	6 425	-	6 425
MUSSALEYAH	11	1 096	4 601	-	4 601
DARB BENI SHU'BAH	43	1 600	6 401	1 737	8 138
ATOUD	21	380	1 740	510	2 250
BISH	21	2 354	10 780	-	10 780
ILHAGO	23	752	3 529	30	3 559
HORQUB	154	2 817	13 367	645	14 012
AR RAYTH	141	1 541	1 085	7 110	8 195
AL RABOOAH	129	407	2 330	-	2 330
ABU ARISH	182	7 275	33 126	-	33 126
WADI JAZAN	53	3 334	14 653	-	14 653
DHAMAD	74	4 993	22 261	-	22 261
BENI QAIS	17	201	805	-	805
AT TAWAL	39	2 263	1C 790	-	10 790
AL MAWSEM	31	796	4 446	-	4 446
AL MADHAYA	31	1 242	5 430	-	5 430
FARASAN	18	969	3 352	-	3 352
AL KHOYAH	135	4 297	20 964	-	20 964
SAMITAH	138	8 252	36 956	438	37 394
AL ARIDAH	608	5 763	29 130	180	29 310
AL AHAD	155	5 181	24 193	-	24 193
TOTAL JAZAN REGION	4 537	85 483	387 161	15 945	403 106

POPULATION OF QASIM REGION, 1394 A.H

EMIRATE	NO OF CENTERS	NO OF HOUSEHLD	SETTLED POPULATN	MIGRANT POPULATN	TOTAL
CITY OF BURAIDAH	1	8 774	69 364	576	69 940
CENTERS ATTACHED TO BURAIDAH	25	909	3 685	2 817	6 502
KHUDAIRA	1	109	880	-	880
KHUB AL KABR	2	91	786	-	786
AL HADYAH	3	102	119	567	686
AL RABI'IYAH	5	210	1 447	210	1 657
AL SHAMSEYAH	12	797	2 759	2 469	5 228
AL TARFEYAH	6	421	1 567	852	2 419
AL LUBAID	25	811	1 472	4 086	5 558
AL MEDREJ	1	504	451	2 802	3 253
HWAILAN	7	160	1 348	-	1 348
AL QUSAY'IYAH	3	104	954	-	954
AL LUSSAIB	1	49	341	63	404
AL MURAID BIBSEYAH	2	206	1 655	-	1 655
AL ARAIDHY	1	25	247	-	247
THARAS	4	153	1 208	-	1 208
AL BASAR	6	180	1 589	-	1 589
AL GHAMAS	4	182	395	975	1 370
AL SHEGGAH	4	225	1 529	267	1 796
AL QUR'AA	3	142	445	507	952
AL DALFA'AH	1	122	106	612	718
AS SHAIHEYAH	1	476	731	2 433	3 164
AL BUKAIREYAH	6	1 086	6 486	690	7 176
MEDREJ	1	104	451	2 802	3 253
HWAILAN	7	160	1 348	-	1 348
AL HALALEYAH	1	139	905	-	905
AL KHUBARA	2	284	2 275	-	2 275
RIYADH AL KHUBARA	3	1 202	3 780	4 188	7 968
UNAYZAH	11	5 025	27 696	6 168	33 864
AL ROGHANI	1	33	230	-	230
WADI ABU ALI	1	13	91	-	91
AL BADAYE'	4	902	6 293	561	6 854
THAMREYAH	7	175	376	522	898
AL OSHAZEYAH	1	49	233	60	293
AL MIDHNAB	14	1 212	5 989	1 395	7 384
AL MURABBA'	4	93	385	180	565
AL AMAR	6	386	1 054	1 104	2 158
AR RASS	12	2 179	14 038	792	14 830
AL SHANANAH	5	222	1 028	495	1 523
KASR BEN AQEEL	6	395	2 503	-	2 503
AL NABHANEYAH	2	278	1 649	99	1 748
AL BETRA	1	31	134	-	134
SABIH	2	116	743	-	743
AL DHEEBEYAH	1	365	1 668	771	2 439
AL DULAIMEYAH	4	656	1 351	2 346	3 697
AL QAREEN	3	358	804	1 275	2 079

DHALI RASHEED	23	1 619	3 476	4 323	7 799
AL BA'JA	6	509	1 040	1 740	2 780
AL KHUSHAIBY	3	238	1 612	-	1 612
SHUBAIKEYAH	14	617	1 562	1 932	3 494
DUKHAN	12	686	2 300	1 752	4 052
RABEEK	5	549	749	2 337	3 086
AL BALGA	2	314	154	1 542	1 696
AIN BEN FAHAID Asya	11	497	2 734	204	2 938
AL JAALA	2	449	499	2 205	2 704
AL ABGEYAH	2	92	178	363	541
TURAIF AL ASYAH	1	50	139	204	343
TANUMA	6	170	654	525	1 179
AL BOROUD	1	905	205	4 938	5 143
KHUSAIBAH	1	189	443	537	980
HUNAIDHAL	5	147	610	432	1 042
AL LADOUD	6	185	788	312	1 100
AL FAWARAH	11	1 173	3 806	3 306	7 112
QUSAIBA	2	176	938	327	1 765
GHAF AL 'UYUN	2	180	265	666	931
ROADH AL 'UYUN	1	166	140	738	878
'UYUN AL JOA	2	337	1 181	900	2 081
OTHAL	2	240	576	939	1 515
NORTH BUGAYAH	11	408	500	2 139	2 639
KAHLA	15	1 619	1 052	7 362	8 414
AGLAT AL SOGOUR	37	2 606	2 296	10 992	13 288
KATAN	7	203	497	786	1 283
AL FAWARAH	42	1 402	4 134	4 017	8 151
THADEJ	5	260	1 388	-	1 388
ATTA	1	120	722	-	722
ATTI	1	54	302	-	302
AL LAFIFAH	2	261	319	1 182	1 501
MUTREBAH	1	71	305	6	311
WEST TARFEYAH	3	61	362	-	362
BUSRA	4	316	196	1 377	1 573
DHAREYAH	36	1 389	4 025	3 003	7 028
AL MUTAYWI	1	92	446	9	455
MESKEYAH	7	260	1 243	216	1 459
SAMOOREYAH	1	163	822	-	822
TOTAL	509	48 724	215 447	101 193	316 640

POPULATION OF HAYEL REGION, 1394 A.H

EMIRATE	NO OF CENTERS	NO OF HOUSEHLD	SETTLED POPULATN	MIGRANT POPULATN	TOTAL
HAYIL CITY	1	6 065	40 248	255	40 502
CENTERS ATTACHED TO REGION	48	3 498	5 062	14 112	19 174
HAFEER	14	775	3 382	726	4 108
JEBBAH	14	727	2 026	1 989	4 015
TURABAH	14	1 564	702	8 064	8 766
BAQ'A	55	5 007	7 100	21 714	28 814
QUBBAH	16	2 677	1 963	12 609	14 572
AL KAHFA	10	823	1 082	3 675	4 757
AL SAB'AAN	27	1 331	2 846	5 142	7 988
AL AZEEM	22	1 751	1 487	8 361	9 848
SAMIRA	38	2 101	3 943	6 915	10 858
AL HALIFAH	58	2 643	8 536	5 346	13 882
AL SULAIMA	28	2 785	3 863	10 821	14 684
AL GHAZALAH	16	1 121	4 776	1 197	5 973
AR RAWDAH	17	967	2 836	3 057	5 893
MOGAG	57	3 833	4 969	17 187	22 156
THUGHUT	31	1 564	5 428	2 958	8 386
TABA	34	2 742	5 406	11 412	16 818
AL HAYET	25	1 986	9 395	1 437	10 832
AL MUSTAJEDAH	15	1 378	2 161	5 742	7 903
TOTAL	540	45 338	117 210	142 719	259 929

POPULATION OF TABOUK REGION, 1394 A.H.

EMIRATE	NO OF CENTERS	NO OF HOUSEHLD	SETTLED POPULATN	MIGRANT POPULATN	TOTAL
TABOUK CITY	9	10 696	74 741	84	74 825
AL AYEENAH	7	183	91	849	940
ADMUJ	7	274	35	1 758	1 793
AL BADI'AH	38	1 051	121	5 979	6 100
TALAH CENTER	1	6	38	-	38
AL QULAIBAH	15	391	294	2 151	2 445
AL AKHDAR	11	144	116	741	857
TAIMA					
TAIMA CITY	16	1 473	4 794	4 425	9 219
ARDAH	14	373	16	2 130	2 146
KUTAYEB	15	831	10	4 365	4 375
TOTAL	45	2 677	4 820	10 920	15 740
EAJR	5	79	7	462	469
TABAWEYAH	8	110	239	405	644
SHAQRA	36	1 855	172	10 749	10 921
AS SHRAF	32	913	94	4 983	5 077
AL BID'	18	765	883	2 580	3 463
DUBA					
DUBA & CENTERS ATTACHED TO CITY	21	1 370	4 237	2 982	7 219
SHAWAG	7	740	898	3 835	3 733
AD DISSA	13	656	313	3 003	3 316
AL MUAYLEH	9	590	361	2 361	2 722
AL KHURAIBA	5	126	600	-	600
SHARMA	9	565	342	2 311	2 653
MUGNA	12	136	556	168	724
TOTAL	76	4 183	7 307	13 660	20 967
WAJH					
WAJH & CENTERS ATTACHED TO CITY	58	2 817	5 760	9 210	14 970
ABU GAZAZ	4	219	78	1 020	1 098
BADA	8	833	446	3 513	3 959
TOTAL	70	3 869	6 284	13 743	20 027
AMLAJ	88	5 398	9 955	13 773	23 728
SHABHA	6	1 048	191	5 538	5 729
TOTAL	94	6 446	10 146	19 311	29 457
TOTAL REGION	472	33 642	105 388	88 375	193 763

POPULATION OF AL BAHAH REGION, 1394 A.H

EMIRATE	NO OF CENTERS	NO OF HOUSEHLD	SETTLED POPULATN	MIGRANT POPULAIN	TOTAL
AL BAHAH					
AL BAHAH CITY	86	5 004	32 082	18	32 100
BILJURASHI	105	6 450	35 000	3 525	38 525
AL MENDAG	37	1 626	10 516	-	10 516
BENI HASAN	53	1 678	10 594	-	10 594
ANAZA & JAMAJEM	4	165	972	-	972
DAOS	44	1 264	7 260	-	7 260
AL QARI	69	1 802	12 143	897	13 040
BEDAH	40	969	4 194	3 126	7 320
AGIG	41	3 194	1 799	14 988	16 787
AL MEKHWAH	179	2 655	12 548	-	12 548
HAMED AL ZENAD	127	3 106	5 261	1 614	6 875
QALWA	171	2 156	8 044	2 406	10 450
ASH SHA'RA	99	1 087	4 908	-	4 908
HAJRAH	192	1 982	6 348	2 118	8 466
NAWAN	24	517	2 077	216	2 293
NEERA	25	668	3 251	-	3 251
TOTAL OF REGION	1 296	34 323	156 997	28 908	185 905

POPULATION OF NAJRAN REGION, 1394 A.H

EMIRATE	NO OF CENTERS	NO OF HOUSEHLD	POPULATN SETTLED	POPULATN MIGRANT	TOTAL
NAJRAN CITY	1	9 149	47 501	-	47 501
JURFEYAH	13	785	3 570	261	3 831
AL OKHDOUD	10	954	4 620	498	5 118
RAJLAA'	10	627	3 192	339	3 531
SHAB BRAN	12	409	1 646	594	2 240
HUDHN	25	967	5 017	-	5 017
ARISA	3	719	2 812	1 395	4 207
SHALYA	4	216	-	1 158	1 158
BER ASKAR	9	307	14	1 638	1 652
MUFJAH	7	709	3 558	24	3 582
KHADHRA	7	732	1 146	3 237	4 383
HARSHAF	11	296	562	924	1 486
HUSAINEYAH	2	1 115	60	6 387	6 447
KHABASH	1	1 718	74	10 173	10 247
HABONA	7	847	2 411	1 668	4 079
THAR	16	1 258	224	6 324	6 548
AL MAJMA	11	310	1 001	453	1 454
HADADAH	22	302	604	942	1 546
AL MAAYEN	12	555	52	2 901	2 953
BADR (MEDHMAR)	28	1 016	1 867	3 228	5 095
YADMA	15	1 623	470	8 442	8 912
HAMA	6	346	156	1 467	1 623
AL WAJEED	4	261	11	1 431	1 442
MUNKHALA	2	235	44	1 137	1 181
SHAROURA	3	1 005	5 856	1 794	7 650
WADIAH	1	108	5 087	-	5 087
TOTAL	242	26 569	91 555	56 415	147 970

POPULATION OF NORTHERN BORDERS REGION, 1394 A.H

EMIRATE	NO OF CENTERS	NO OF HOUSEHLD	SETTLED POPULATN	MIGRANT POPULATN	TOTAL
AR'AR					
CENTER OF EMIRATE	24	5 187	21 768	11 583	33 351
JADEEDAT AR'AR	7	25	146	-	146
TURAIF	7	1 978	9 761	2 688	12 449
AL MA'ANEYAH	2	446	223	2 508	2 731
AL OWAIGLEYAH	5	12 331	929	6 711	7 640
AD DWAID	10	1 167	160	7 041	7 201
LUKA	4	848	110	5 676	5 786
RAFHA	11	2 333	6 772	8 931	15 703
NEENA	23	2 061	746	11 712	12 458
SHUBAT NESAB	6	1 478	568	9 651	10 219
UM RUDHMA	10	1 045	66	6 174	6 240
SAMOUDAH	4	101	108	5 193	5 301
NESAB	3	81	25	498	523
SAMAH	10	448	6	3 060	3 066
HAZM AL JALAMEED	2	263	239	1 497	1 736
UM KHUNSUR	2	651	1 039	3 156	4 195
TOTAL	130	19 345	42 666	86 079	128 745

POPULATION OF JOAF REGION, 1394 A.H

EMIRATE	NO OF CENTERS	NO OF HOUSEHLD	SETTLED POPULATN	MIGRANT POPULATN	TOTAL
SAKAKA CITY	1	3 453	10 536	10 440	20 976
CENTER ATTACHED TO REGION	17	1 492	3 109	6 654	9 763
ZALOUM	1	76	179	231	410
AL SHWAIHTEYAH	3	607	361	5 028	5 389
TALAT AMMAR	1	229	626	222	848
AL TAIRY	22	565	109	2 877	2 986
DAWMAT AL JANDAL	10	2 000	10 114	2 373	12 487
AL MAROUT	5	441	2 962	-	2 962
AL ASSAFEYAH	2	331	354	1 464	1 818
NABK ABO KASR	18	580	2 995	2 067	5 062
TABARJAL	4	257	1 208	45	1 253
MAYGOO	1	232	1 540	-	1 540
TOTAL	85	10 243	34 093	31 401	65 494

POPULATION OF QARYAT REGION, 1394 A H

EMIRATE	NO OF CENTERS	NO. OF HOUSEHLD	SETTLED POPULATN	MIGRANT POPULATN	TOTAL
QARYAT					
CITY OF QARYAT	4	2 491	8 692	5 889	14 581
HADITHA	3	154	802	51	953
KAF	5	150	569	252	821
GARAGER	3	43	84	198	282
AL MABEYAH	5	158	362	351	713
EASAWEYAH	26	439	2 131	684	2 815
AL HOAJ	2	36	288	-	288
HADRAJ	2	19	118	-	118
MUGHAYRA TUBAIK	2	33	23	78	101
HALAT AMMAR					
CENTER OF EMIRATE	8	501	1 663	306	1 969
THAT AL HAJ	4	8	23	-	23
BEN BER HERMAS	5	133	386	126	512
TOTAL	17	642	2 072	432	2 504
HAGL					
CENTER OF EMIRATE	14	854	3 050	1 095	4 145
DURRAH	2	10	70	-	70
ALGAN	5	541	94	2 562	2 656
MADSOUS	2	92	52	396	448
ABA AL HANSHAN	6	211	25	984	1 009
TOTAL	29	1 708	3 291	5 037	8 328
TOTAL OF REGION	98	5 873	18 432	12 972	31 404

APPENDIX C*

JUBAIL INDUSTRIAL COMPLEX

POWER PEAK LOAD TABULATION

SUMMARY

(1979 - 1983)

TYPE OF THE LOAD	1979	1980	1981	1982	1983
Primary Industry	-	7	46.2	158.2	975.6
Secondary Industry	-	-	-	70	343.5
Support Industry	-	6.5	26	64.5	77
Camps 1 Thru 11	55	65.8	91.8	91.8	91.8
Water	4.8	11.2	18.7	18.9	22
Community Airport	-	-	14.5	63.7	159.7
Materials Handling	-	-	-	14.55	15.55
Sea Water	-	-	-	16.12	45.1
Sewage, Treatment	0.82	2.72	18.12	18.12	18.12
Infrastructure	-	5.3	8.4	15.6	14.7
MW Power Grand Total	60.62	98.52	223.72	531.49	1763.07

Source: Bechtel - Jubail - Saudi Arabia, 1978

JUBAIL INDUSTRIAL COMPLEX

POWER PEAK LOAD TABULATION

SUMMARY

(1984 - 1987)

TYPE OF THE LOAD	1984	1985	1986	1987
Primary Industry	1421.6	1599.6	1900.6	1990.6
Secondary Industry	470	470	470	513
Support Industry	89.5	89.5	102	102
Camps 1 Thru 11	91.8	91.8	91.8	91.8
Water	23.7	25.8	28.1	33.2
Community Airport	242.9	295.4	347.9	400.4
Materials Handling	15.55	15.55	15.55	15.55
Sea Water	54.75	54.75	64.42	64.42
Sewage, Treatment	18.12	18.12	18.12	18.12
Infrastructure	3.2	6.1	6.1	-
MW Power Grand Total:	2431.12	2662.02	3044.59	3229.09

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